Spinning by Machinery

These machines twist the fibres of the cotton plant into long continuous threads. They are doing the work which used to be done by the hand spinsters only on a very much larger scale.

THE ROMANCE OF MODERN MANUFACTURE

A POPULAR ACCOUNT OF THE MARVELS OF MANUFACTURING

BY

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"THE ROMANCE OF MODERN ELECTRICITY," "THE ROMANCE OF MODERN PHOTOGRAPHY," "SCIENTIFIC IDEAS OF TO-DAY, &c., &c.

WITH 28 ILLUSTRATIONS & 16 DIAGRAMS

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PREFACE

THOSE of us who have grown up with the results of *Modern Manufacture* around us are apt to miss the romance of the subject. Indeed, it is difficult for us to realize how very different were the conditions in which our great-grandfathers, and even our grandfathers, lived and worked. In the present volume the author has endeavoured to trace the evolution of the different industries, and to describe in everyday language the methods of modern manufacture in our principal industries. In order to keep the book as readable as possible, he has omitted many names and dates, but sufficient detail is given to enable the general reader to form a clear conception of the different subjects.

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CONTENTS

CHAPTER I

THE STARTING-POINT

CHAPTER II

HOW WE CAME TO SPIN BY MACHINERY

CHAPTER III

WEAVING BY MACHINERY

CONTENTS

CONTENTS

CHAPTER XI

THE AUTOMATIC NEEDLE-MAKERS

CHAPTER XII

THE ROMANCE OF THREAD-MAKING

CHAPTER XIII

THE AUTOMATIC SHOEMAKER

CHAPTER XIV

MANUFACTURE OF POTTERY

CONTENTS

CHAPTER XVIII

MAKING SWEETS BY THE TON

CHAPTER XIX

THE MECHANICAL BAKER

CHAPTER XX

CLOCKS AND WATCHES

CHAPTER XXI

THE MANUFACTURE OF IRON

CONTENTS

CHAPTER XXV

CONCLUSION

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

LIST OF DIAGRAMS

THE ROMANCE OF MODERN MANUFACTURE

CHAPTER I

THE STARTING-POINT

We sometimes hear people say that they wish they had lived in "the good old times," when people had to take things easy. No rushing off to catch an express train, and flying across the country at a break-neck speed; no constant hurry and bustle such as is necessary in modern business-life.

It is all very well to talk of the life of ease which some suppose our forefathers to have lived. Things certainly went more slowly, but let us imagine a journey over wretched roads from Edinburgh to London in the month of December, the passengers huddled together in a stage-coach. Compare this journey of several days and nights with the comfortable eight hours' run of to-day. We may spend the forenoon in the Scottish capital, and setting out after lunch, we find ourselves in London in good time to get off to bed. We have not even had the discomfort of cold feet, for the carriages are comfortably heated.

We have not felt what hunger is, for we have dined on the train, as comfortably as at home. We have not even suffered from stiff limbs or aching back, for we have had plenty of room to move about. All this comfort and luxury have cost us a mere fraction of what our forefathers had to pay for the misery and discomfort which they had to endure. There are some interesting records of *the miseries of travelling* to be found in the journals of a century ago.

If our forefathers could return to space and time, they would, no doubt, consider our present life a paradise compared with "the good old times." They would certainly be surprised to find that even the working-classes could possess many things which, in their time, were counted luxuries for the very rich. It was not that such things could not be made in their time, for man has been an expert workman for ages past. A walk through some of the Eastern departments of the British Museum in London will satisfy us that even the ancients were able to make exquisite fabrics, pottery-ware, glass-ware, etc., the details and quality of which it would be difficult to excel at the present time. But picture the laborious task of producing these, and the consequent limited production. I remember seeing an Indian figured shawl which required three generations to produce it, the father being followed by his son, and then by his grandson. The one shawl, truly a wonderful piece of work, was the life-work of three generations.

It is obvious that our progress has been in devising inanimate machines capable of doing work which until recently was thought to require human hands and brains.

THE STARTING-POINT

The real beginning of this progress dates only from the opening of the nineteenth century. From that time forward advances have been made with leaps and bounds. Till then we find that the processes of manufacture continued very much the same for thousands of years, and then there came a great change—indeed, we might call it a complete revolution. Within a single century the whole aspect of manufacture is changed entirely. We need not suppose that suddenly a generation of men arose superior to all their forefathers, but there must have been some real cause for so rapid a development of modern manufacture. It is not difficult to put one's finger on the one factor which altered the face of things. It was the advent of the steam-engine which placed *power* in man's hands.

Up till the close of the eighteenth century man had been dependent upon what we usually call *natural* sources of power. In addition to his own energy he used that of horses or other animals, the energy of running water, or of the fickle wind. The steam-engine provided him with a power immensely greater than anything he had previously imagined.

We know that all the energy we can call to our aid is already existent in Nature. In this case which we are considering man found a means of transforming the heat energy locked up in coal into mechanical energy by means of this machine which we call a steam-engine. The to-and-fro motion of the piston provides us with *power*, which we may utilize directly as in the steam-hammer, or by means of a crank and fly-wheel we may convert it into a rotary motion, and thereby turn the driving shafts of our factories and workshops. But first of all we wish to see how we came to have steam-engines.

When one of the scientific journals was reviewing one of the writer's former *Romance* books, the critic said: "We take it that the duty of the writer of such a volume is very largely to rob his subject of its atmosphere of romance by showing its gradual development and the reasonableness of its results." That is exactly wherein the real interest lies. If we had to record merely that on a certain date a certain man invented a certain complicated machine, the reader would not be interested; such things could only happen in fairy-tales. If, on the other hand, we can trace how a complicated machine has been evolved gradually from very simple beginnings—if we can trace out the origin of an invention—there is a genuine interest attached to it. The farther back we can take the genealogic tree, the greater is the interest, provided we can show a true descent.

In sketching the history of the steam-engine it is usual to go back to 130 years B.C., when Hero of Alexandria made a globe to revolve by steam escaping from two projections upon it. It has always seemed to me to be taking the genealogic tree back too far. It is most improbable that those who invented the earliest steam-engines had ever heard of Hero's ancient experiment, which was merely a revolving fountain.

Early in the seventeenth century Giovanni Branca caused a wheel to revolve by the impact of a jet of steam; but this Italian experiment was not well known, and there is no evidence that this idea was known to the inventors of the steam-engine. For this reason I should not count it one of the ancestors from which the steam-engine has descended. What really led to the invention of the steam-engine was the necessity of pumping large quantities of water out of coal-mines.

"Sea-coal," as it was first called, owing to its being brought to London by ships, had come into general use for iron-smelting. When looking through the specifications of early patents I was surprised to find that a patent was granted to Lord Edward Dudley in 1621 for "the use of coal for iron work." Someone may wish he could own a patent for the use of coal for boiling water. However, long after Lord Dudley's patent had expired coal was in great demand for industrial purposes. Coal-mining in these days was subject to a "grand inconvenience." The best coal was found deep down in the earth, but the excess of subterraneous water was so great that it was "not worth the expense of drawing it, by the great charge of horses or hand-labour." The most pressing industrial problem of the day was how to pump up this water without enormous expense.

About the middle of the seventeenth century the Marquis of Worcester was imprisoned in the Tower of London for his loyalty to the cause of Charles I. During his solitary confinement Lord Worcester observed the lid of a kettle forced upwards by the enclosed steam. This simple everyday occurrence seems to have suggested the idea that steam might force the water out of the deep coal-mines. The ingenious nobleman devised a very simple means of doing so. This he describes in a book which is entitled *A Century of Inventions* (1663). This title does not mean, as one might suppose, that the book contains the inventions of a certain century. It is a description of one hundred inventions, or, rather, suggestions, made by the noble Marquis. I remark upon this, as the title is sometimes quoted as *A Centenary of Inventions*.

Lord Worcester described his invention as "an admirable and most forcible way to drive up water by fire." The principle of this invention is generally stated as follows: He caused a vacuum in a vessel by condensing steam in it, so that water would rush up by a pipe to fill the empty space, whereupon it was forced still higher by a second injection of steam. This, however, seems to be reading between the lines. The Marquis states clearly in his sixty-eighth article that his method of raising water by fire is "not by drawing or sucking it upwards." The experiments which he mentions suggest that he simply forced the water upwards by the pressure of steam. The vacuum vessel was introduced by a miner, Thomas Savery, in 1698, who obtained a patent for a fire-engine for raising water.

One finds very often that the Marquis of Worcester is described as "the inventor of the steam-engine," while other writers give the credit to Savery. But neither of these inventors made a steam-engine as we use that word now. They had no thought of obtaining mechanical motion from steam-power. I am not overlooking the fact that the Marquis of Worcester, in one of his later articles, seems to hint at obtaining motion from his "semi-omnipotent engine," but I think that all will agree that these very vague suggestions did not lead to the invention of the steam-engine.

It will be understood that these "steam-pumps" of the Marquis of Worcester and Thomas Savery had no going parts; they were merely means of forcing up water from a depth by the use of steam.

About the same time as Savery was busy with his steam-pump, a Derbyshire blacksmith, Thomas Newcomen, invented what I should call a real steam-engine, having a piston moving to and fro within a cylinder. Of course, Newcomen's idea was to solve the pressing problem of the day—to pump water up from the mines. The plan he adopted was a very simple one. The moving piston pulled down one end of a beam, the other end of which pulled up the plunger of a water-pump.

It is generally stated that Newcomen took out a patent for his engine in 1705. Desirous of seeing the original diagrams, I went to look these up in one of our Patents Libraries. I was surprised to find that Newcomen's name does not appear in the index of patentees, but remembering that some of the early patents were taken out under the names of agents, I looked through the specifications for the year 1705. This was a light task, for it happens that only one patent was taken out during the whole of that year, and that related to the refining of gold and silver. A search through the specifications for some years before and after 1705 showed that Newcomen had never sought the protection of the Patent Office.

In the earliest description which I can find of Newcomen's engine it is made perfectly clear why he did not apply for a patent. I refer to Switzer's *Hydrostaticks and Hydraulicks* (1729). Under the heading "Description of the Engine to raise Water by Fire, as improv'd by Mr. Newcomen," Switzer says: "This ingenious Gentleman, to whom we owe this late invention, has, with a great deal of Modesty, but as much Judgment, given the finishing Stroke to it. It is indeed generally said to be an improvement to Mr. Savery's Engine; but I am well informed that Mr. Newcomen was as early in his invention as Mr. Savery was in his, only the latter, being nearer the Court, had obtained his Patent before the other knew it; on which Account Mr. Newcomen was glad to come in as a partner to it." Had there been any patent agents in those days, Newcomen would have been advised that his invention was in no way an infringement of Savery's patent. As already stated, Newcomen employed a piston and cylinder, while Savery's so-called engine had no going parts.

It seems as though Newcomen's modesty prevented him seeing that his idea was superior to that of Savery. He apparently allowed his own plans to lie idle until Savery's pumps were found insufficient. It is evident that Switzer was impressed with Newcomen's idea, for he describes it as "undoubtedly the beautifullest and most useful Engine that any Age or Country ever yet produced."

In making out a genealogic tree of the steam-engine's pedigree, I should be inclined to write the name of Thomas Newcomen in bold type, although some writers maintain that he has no real claim to have invented anything new, all the ideas he used having been known already. If inventions were to be dealt with in this fashion, we should not have a very large patent record. Newcomen discovered nothing, but he certainly invented a practical steam-engine, and to my mind this was the real starting-point. Pistons and cylinders were in use for water-pumps and air-pumps before Newcomen's time, and these appeal to me as being more entitled to be called ancestors of the steam-engine than Savery's and Worcester's suction and forcing pumps.

Placing the piston and cylinder air-pumps as the first in our genealogic tree, I should follow with a gunpowder-engine invented by the Dutch scientist Huyghens in 1680. This invention consisted of a strong cylinder and piston. A charge of gunpowder was exploded in the cylinder, the piston being kept up while the explosion took place. The explosion drove out the air from beneath the piston, which thereupon fell with considerable force, being pressed down by the weight of the atmosphere. A heavy weight could be lifted by the falling piston, by fastening a rope or chain to the piston-rod, then over a pulley-wheel and down to the weight. This engine never came into practical use, but it is of special interest as being a direct ancestor of the steam-engine, as we shall see.

A young French doctor, Denis Papin, suggested in 1690 that steam might be used in place of gunpowder in Huyghens' engine. Placing a little water in the cylinder, he heated it so that the air was driven out of the cylinder, and when it was filled with steam he withdrew the source of heat and cooled the cylinder, so that the steam condensed produced a vacuum, and the piston was forced down by atmospheric pressure in exactly the same manner as in the gunpowder-engine. One improvement which Papin made in his "steam-engine" was to lock the piston in its highest position before he withdrew the source of heat, so that he could release the piston at will, and thus apply the power when he desired. Huyghens let the downward stroke of his piston act at the moment of the explosion.

These two inventions were made in Newcomen's time, and if he had never seen one of these primitive engines at work, he had undoubtedly heard of their simple action and of the great weight which they could lift. Could such a power not be applied to raising water out of coal-mines? This would be a very natural question when the outstanding problem of the day was how to overcome the subterraneous water in mines. Newcomen would, no doubt, see that one great drawback was the very slow action of Papin's "steam-engine." A little steam had to be generated specially for each stroke; this was done within the cylinder itself. Newcomen suggested a separate boiler, in which steam could be constantly kept up and drawn upon at each stroke. This would save a great deal of time, for as soon as the engine made one stroke he had steam ready for a second stroke, and so on.

It will be observed that the principle of Huyghens' gunpowder-engine and Papin's and Newcomen's "steam-engines" is the same in each case. It is the pressure of the atmosphere forcing the piston down when a vacuum is produced below it which does the work. We therefore speak of these three inventions as *atmospheric engines*.

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MODERN MACHINERY IN DISTANT LANDS

This large boiler is on its way to a tea estate in Ceylon. Observe the elephant at the rear helping to push the load along with his trunk.

Newcomen applied the power in the same way as the others, only he substituted a lever or beam for the pulley-wheel, round which the chain passed in the former methods. As already stated, Newcomen caused the piston-rod to pull down one end of the beam, while the other end pulled up the plunger of the water-pump—a simple seesaw arrangement. Newcomen's engine must be reckoned as the first practical steam-engine; it did yeoman's service in connection with the pumping of mines.

We are all familiar, no doubt, with the story of the boy Humphry Potter, who, finding it an irksome duty to open and shut the valves as required in a Newcomen engine, attached cords and catches to connect the valves with the moving beam, thus making the whole action automatic. It seems very doubtful if this ingenious boy ever existed except in imagination. Switzer, when writing the history of Newcomen's engine in 1729, does not mention this incident, which is narrated for the first time in 1744, or thirty-one years after it was supposed to have taken place. I cannot imagine Switzer omitting to record any fact of this kind; he even relates such trivial incidents as the following:

Referring to Savery's so-called engine, Switzer writes: "I have heard him say myself, that the very first Time he play'd it, was in a Potter's House at Lambeth, where tho' it was a small Engine, yet it forc'd its Way thro' the Roof, and struck up the Tiles in a Manner that surpris'd all the spectators." Surely the incident of Humphry Potter would have been of much greater historical interest!

An original drawing of Newcomen's first engine is preserved in the *William Salt Library* at Stafford (England), and this shows the automatic means of opening and shutting the valves. The drawing is dated 1712, which was the date of erection of the engine, whereas Humphry Potter is stated to have made his improvement in 1713. It might be argued that the old drawing referred to may have been made after 1713, but I fear there is no evidence for or against this suggestion.

It has been suggested that Desaguliers, the first to record the story, invented or introduced the story, thirty-one years later, in order to detract from Newcomen's invention, but it is more charitable to suppose that the story originated in a misunderstanding. Indeed, there seems room for such an error, for in the original drawing, a photograph of which I have seen, the parts are all lettered, and a list of them appears on the drawing itself. The automatic arrangement is described as "Scoggan and his mate who work double to the Boy: *y* is the axis of him." All these terms were names given to different parts of the engine.

Personally, I do not credit the story of Humphry Potter, for I do not believe that such a careful historian as Switzer could overlook so important a fact. Switzer wrote much nearer the date of the supposed incident than Desaguliers did; a generation had passed before the latter recorded the story.

While Newcomen's engines were busy pumping up water from coal-mines, and thus enabling the iron-smelters and others to obtain the necessary fuel, other industries were being set on foot. Several cotton-mills had been erected, and the necessary power was obtained by horses where no running water was convenient. The horses walked round and round turning a gin, such as one sees at many farms to-day in connection with the thrashing of corn.

In 1780 a mill-owner in Manchester put in one of Newcomen's engines to pump water to a height, and thus obtain the necessary running water to turn a large water-wheel. Some writers have made fun of this idea, but it was a very natural one, for at that time the engine was looked upon only as a means of pumping up water. This mill-owner did us a good turn, for he provided the first connecting link between the steam-engine and the driving of machinery.

It was not long before someone, when fitting up another factory, suggested dispensing with the water-wheel and connecting the engine directly to a crank and fly-wheel. Cranks and fly-wheels were in use already in connection with manual pumps and other devices. Instead of making the end of the seesaw beam pull up the plunger of a pump, the beam was connected by a strong rod to the crank of a very heavy fly-wheel. This, however, did not make a very efficient machine.

While these pioneer mill-owners were making bold attempts to obtain the power necessary to drive their newly invented spinning machinery, it so happened that a model of Newcomen's engine, which belonged to the Natural Philosophy Department of Glasgow University, went out of working order. The model was handed to the College mechanic to be repaired. This mechanic, although a most ingenious youth, and working under the patronage of the University, found his business anything but lucrative. However, it is not so much the man as the machine with which we have to deal at present. This youthful "mathematical instrument maker" soon repaired the Newcomen model, which may be seen still at the University. He was impressed with the great waste of heat and the imperfect working of the engine, and he began a scientific investigation of the causes of these defects. It soon occurred to him that the alternate heating and cooling of the cylinder was a great waste, and that this defect might be remedied by allowing the cylinder to remain hot by condensing the steam in a separate vessel. He also added an "air-pump" to exhaust the condensing vessel, so that the steam would rush into it from the cylinder. His ingenuity did not end there, for instead of using the steam merely to produce a vacuum, as Newcomen had done, he took advantage of the expansive power of steam, which was already a well-known fact. By increasing the heat of his boilers, and thereby increasing the steam-pressure, he caused the steam on entering the cylinder to force the piston along to the end of the cylinder. Then came the vacuum as before, but instead of leaving the atmosphere to force in the piston, he closed in the end of the cylinder and admitted steam above the piston, so that the piston was forced back again with a far greater pressure than that of the atmosphere. In short, he caused the steam and the vacuum to act simultaneously and alternately on both sides of the piston.

Although this mechanic at the University of Glasgow was at that time quite unknown to the outside public, his name—James Watt—is now familiar to every educated person. We often speak of Watt as the inventor of the steam-engine, and so he was in a very real sense. His engine was not merely an improvement on Newcomen's; it was a distinctly new machine. Watt was the first to apply the expansive force of steam to obtain *power*. We should remember that this great victory was not won without a severe struggle and much personal sacrifice on the part of Watt. It took him ten years of patient toiling to devise the practical means of carrying out his ideas. Sometimes he was quite despondent. In a letter to Dr. Black, the discoverer of the doctrine of latent heat, Watt wrote: "Of all things in the world, there is nothing more foolish than inventing." This was said with no light heart.

No one can fail to be interested in the story of James Watt's life, but at present we must confine our attention to the machine which brought about the great development of modern manufacture. Watt's steam-engine soon replaced Newcomen's atmospheric engine for the pumping of mines. As illustrative of the great advance Watt had made, I need quote only one instance. A coal-mine at which three pumps were used adopted Watt's engines in place of Newcomen's, which had been previously used there. The result was that this one mine saved over seven thousand pounds sterling in fuel during the first year.

It is obvious that Watt's invention would give a great impetus to coal-mining. We can quite imagine that many mines which had not been paying their way would become profitable concerns with the great saving of their bill for fuel. It was not long before this new motive-power was welcomed by mill-owners to drive their machinery, and they could thoroughly appreciate the statement that one of these new engines was equal to so many "horse-power," a term of comparison we use still.

Having traced the evolution of the steam-engine to the point at which it became the source of power for industrial purposes, we need not follow it in its further improvements. We have completed the genealogic tree as under:

1650. Guericke invented the air-pump, with its piston and cylinder.

1680. Huyghens invented a gunpowder-engine, in which the explosion produced a vacuum beneath the piston in a cylinder, causing the atmosphere to force down the piston and lift a weight.

1690. Papin suggested the use of steam in place of gunpowder to produce the necessary vacuum.

1698. Newcomen added a separate boiler, so that steam had not to be generated specially for each stroke. He applied the lifting power to work a water-pump for mines.

1769. Watt added a separate vessel for condensing the steam in, and he made use of the expansive force of steam to move the piston in both directions. This was the invention of the steam-engine as we know it now. Watt's engine did not come into practice till 1790.

Some readers may question the validity of the first item in the foregoing list, but just as the electric motor is the converse of the dynamo, so were these early engines the converse of the air-pump. We supply mechanical motion to the dynamo, and we obtain an electric current. We supply electric current to the motor, and we get mechanical motion. In the same way we supply mechanical motion to the air-pump, and we get a vacuum, while in these early engines we supplied a vacuum and obtained mechanical motion. The air-pump was undoubtedly a direct ancestor of the power-engine, and I have no doubt it was the backward suck of an air-pump which suggested the gunpowder-engine to Huyghens.

In omitting the "engines" of the Marquis of Worcester and of Thomas Savery, I do not seek to belittle the importance of these inventions, but, as already explained, these do not appeal to me as being direct ancestors of the power-engine, with its moving parts. I have placed Newcomen's engine under the date of Savery's patent, as it is clear from Switzer's personal statement that Newcomen "was as early in his invention as Savery was in his."

CHAPTER II

HOW WE CAME TO SPIN BY MACHINERY

It is obvious that primitive man had but two requirements—food and clothing. Our present subject has to deal with the latter. Advancing from fig-leaves to coats of skin, man sought to provide himself with more comfortable apparel. In time he hit upon the idea of twisting the hairs or wool of animals into continuous threads, and by interweaving these together he made the first step in textile manufacture.

By-and-by man found that the fibres of the inner bark of the flax-plant could be treated in the same way, and so what we know as linen yarn or thread was produced. At a very early date man also observed that the cocoon, or wrapping which enclosed the chrysalis of a certain caterpillar, was made of a very fine, glossy fibre, wound round and round. This was burst open when the moth had developed, but if taken before this stage the long fibre could be unwound, and a number of these, when twisted together, produced what we now call silk yarn or thread.

Away back in the world's history man found also that the soft downy substance contained in the pods of certain plants could be twisted, so that its fibres made a continuous thread, and in this way we came to have cotton yarn or thread. The Cotton Industry is of so outstanding importance in Great Britain that we shall confine our

FIG. 1.—A PRIMITIVE SPINDLE FOR MAKING THREAD.

attention to the spinning of cotton. We wish to follow the steps by which this gigantic modern industry has been built up.

There seems to be no doubt that spinning and weaving

SPINNING

were the earliest arts practised by man. We find these arts invented independently by savage people. When Columbus discovered America he found the natives wearing cotton cloth made by their primitive methods.

The ancient method of spinning was very simple. The bundle of fibres which was to be spun into thread was placed on a stick called *the distaff.* Holding this under the left arm, the spinster would draw out the fibres of cotton to the required fineness. These were then attached to a notch on the end of a spindle (Fig. 1) made of wood or iron, and having a small ball of clay at its centre. The spinster then caused this toplike *spindle* to spin round, and as it receded from the spinster the necessary twist was given to the *yarn*, or thread. Whereupon the spinster would wind the twisted yarn on to the spindle, and again fixing the thread in the notch on the top of the spindle, she would proceed to twist another length of fibres, and so on. The twist given to the fibres would not come undone, as the fibres would cling to one another and maintain their new positions.

As the cotton-plant grew profusely in India, the Hindoos became expert spinners, and when our merchants opened up business with India we bought large quantities of cotton cloth from that country, although the woollen weavers in Great Britain made a desperate struggle to keep these goods from being used.

To show how keenly these weavers felt the introduction of cotton goods, we may refer to the hanging of a common criminal in Ireland in 1734. It so happened that the convict had been a weaver at one time, so the weavers of

Cork, where the execution took place, dressed him up in cottons on the day of his hanging, and encouraged him to use the occasion for denouncing the use of cotton. In those days the convict was allowed to address the crowd which had gathered to see his hanging, so this fellow made a speech in which he declared that all his misdeeds could be traced to this pernicious practice of wearing cottons. He concluded his last address with these words: "Therefore, good Christians, consider that if you go on to suppress your own goods, by wearing such cottons as I am now clothed in, you will bring your country into misery, which will consequently swarm with such unhappy malefactors as your present Object is; and the blood of every miserable felon that will hang after this warning from the gallows will lie at your doors."

To return to the spinning of cotton by the Hindoos. We find many records describing the great skill attained by them. Some of the muslin imported from India at the end of the seventeenth century was so extremely fine that "when laid upon the grass, and when the dew has fallen upon it, it is no longer discernible." As much as thirty shillings per yard was paid for some of these fine cotton cloths, which "could scarcely be felt in the hand, and the thread of which was scarcely discernible." The descriptive name given to some of these fabrics was "woven wind," and it is recorded that a Mogul Emperor, observing his daughter clad in semi-transparent tissue, rebuked her, whereupon she assured him that her robe was composed of not less than nine folds of muslin. Some of the records of the transparency of these early productions reminds one of Hans Andersen's tale of *The Emperor's New Clothes*. It will be remembered how two rascally weavers worked at an empty loom, pretending to weave cloth which they declared would be invisible to all foolish persons and to those who held positions of which they were not worthy. They succeeded in their trickery for some time, as each person, seeing no cloth, and believing this to be a proof of something wanting within himself, pretended to see and admire the fabrics which did not exist, until a child declared that the Emperor wore no fine clothes, but his shirt only.

To return to realities. It is evident that the spinners of long ago could make yarn of the finest quality imaginable, but it is obvious that the quantity produced by hand must have been extremely small. In order to hasten the process of spinning, the spindle was mounted on a stand, and kept in continuous and regular motion by a hand-wheel. In some cases a treadle was added, so that the wheel might be turned by the foot, leaving both hands free to manipulate the yarn. In the most improved form of spinning-wheel the twisting and the winding were performed simultaneously. The spindle, which was placed horizontally, revolved at a quick speed, putting the necessary twist upon the string of fibres in the same manner as the ancient spindle. At the same time the twisted thread passed over a bent arm, or *flyer*, which, with the bobbin, revolved at a slower rate and wound the thread on to the bobbin.

When the spinning-wheel was introduced into Great Britain about the middle of the fourteenth century, it soon displaced the distaff and spindle. Although the rate of spinning was increased, the quality of the yarn produced still depended upon the skill of the individual spinster.

At this time spinning was practised in almost every household, and many of the gentlefolk were proud of the very fine yarn which their *spinsters* could produce. The Royal Society took notice of the achievements of one Norfolk lady, who spun a single pound of wool into a continuous thread measuring almost forty-eight miles in length. This record, however, was left far behind by a Lincolnshire lady, who spun the same weight of wool into one continuous thread, measuring ninety-five and a half miles.

About the middle of the eighteenth century the method of weaving by hand was improved, as we shall see in the following chapter, and the increased production of the weaver called for a hastening of the spinsters' productions. It was the custom for the manufacturers to give out the warps to the weavers, allowing the latter to find the wefts to interweave with these. The weavers depended very largely upon the womenfolk in their own households to spin the necessary yarn for weaving. It was soon found that the women could not keep pace with the weavers, and it very often happened that weavers had to make excursions to considerable distances in order to get sufficient weft to keep them going. This meant a loss of production, and soon became irksome. Several attempts had been made to hasten the methods of spinning, but with no practical result up till about 1764. About this time a humble weaver at Blackburn (England) hit upon a useful idea. It is said that his wife's ordinary spinning-wheel was accidentally overturned upon the floor, when he observed that the wheel and spindle continued to revolve for some time. Looking at the spindle in its upright position, it occurred to him that a number of spindles fixed in this position might be driven by the same wheel. After some years of careful experimenting, this weaver, James Hargreaves, invented a simple machine, with which the spinster could spin ten separate threads at one time in place of one thread only. Hargreaves called his machine a spinning-jenny, after his wife, whose Christian name was *Jenny*. It was impossible for the spinster to hold ten different *rovings** in her hand, so a travelling-bar was placed on the machine. This horizontal bar, or clasp, was not unlike a parallel ruler, which could be opened to let the rovings pass freely through, and then closed tight when sufficient length had been taken through to reach the spindle. The revolving spindles applied the necessary twist, and this length of rove was gradually wound on to the spindles. Then the clasp was once more opened, and moved back to catch and hold the rovings again at the requisite distance. This moving clasp took the place of the spinster's fingers in the simple one-thread spinning-wheel.

Poor Hargreaves was sorely misunderstood by the

* A roving is a thickish coil of wool or cotton fibres with a slight twist given to it. There is no strength in this roving, but from this flimsy condition it is drawn out and twisted, whereupon it forms a compact and strong thread.

spinners in his neighbourhood. They feared that such machines would drive them out of employment. A crowd of them broke into Hargreaves' house and smashed his machine to pieces. As we go along we shall find this stupid cry, "Men, not machines," repeated in other branches of the industry. Hargreaves fled to Nottingham, where he took out a patent for his spinning-jenny in 1770, but the manufacturers combined together to deprive him of his patent on the ground that he had previously sold one of the machines. Some years later poor Hargreaves died in obscurity, friendless and penniless, but by that time the manufacturers were making money by the introduction of this labour-saving machine.

It will be understood that before the cotton-wool was spun into thread by Hargreaves' spinning-jenny the cotton had to be made into a loose roving. This was done originally by *combs*, or *cards*, held in the hands; the repeated action of these caused the cotton fibres to lie more parallel to one another. Hargreaves had given some assistance in fitting up a cylinder carding machine, in which one card was fixed, while the other, in the form of a cylinder, revolved against it. The cost of preparing the roving was greatly lessened by such means, and the roving was then spun into yarn on the spinning-jenny.

While poor Hargreaves was being persecuted for his inventive genius, another man in a humble position was busy trying to solve the problem of spinning. This man, Richard Arkwright—or, as he was called then, Dick Arkwright—was not connected with the industries of spinning and weaving. He was a barber and hairdresser in Preston. His small shop was in an underground cellar, and, finding business very slow, he attracted customers by placing a large placard above the entrance to his shop announcing that "the subterraneous barber shaves for a penny." Later on he reduced his charge to one halfpenny, but ultimately he abandoned this business, and became a traveller in dyed hair, much used at that time, owing to the general practice of wearing wigs. Arkwright found this new business a very profitable one, and, like a wise man, he remembered that *it is not what we earn, but what we save, that makes us rich.* He soon had some money saved, and this enabled him to spend some leisure time experimenting in mechanics, which subject had always been a fascination to him.

Although Arkwright seems to have given all his spare time at first to a futile attempt to accomplish the impossible task of perpetual motion, he soon turned his attention to something of more practical interest. He was hearing continually about the trouble that weavers were experiencing in obtaining weft to keep them employed at their looms. Possibly he may have heard a good deal about this from some of the customers who came to his subterraneous barber's shop, and probably he had heard discussions regarding the possibility of hastening the process of spinning by machinery. There had been several attempts made before Arkwright's time, and, although unknown to him, Hargreaves was then at work on the same problem.

Arkwright became so engrossed in the inventing of such a machine that he gave up his whole time to it, determined to solve the problem and produce a practical machine. He found this no light task. His savings disappeared, for experimenting and model-making are expensive things, and poor Arkwright fell into very distressed circumstances. Yet he was convinced that he would soon reach the goal; but, alas! his poor wife, finding that he was determined to continue against all her remonstrance, could stand it no longer. In a rage she smashed his models to pieces, thinking this would mean the end of all her troubles; but this was more than the poor inventor could stand, and so they separated. Poor and friendless, Arkwright worked on at his model-making until he had perfected his original idea. A firm of stocking-weavers took an interest in Arkwright, and enabled him to obtain a patent for his spinning-frame.

It will be remembered that Hargreaves' spinning-jenny merely enabled the spinner to operate a number of threads at one time, but the spinner had to draw out the threads as before by moving the bar which clasped the rovings. Arkwright's machine was entirely automatic, and when set in motion performed all the operations of spinning. The only duties left to the spinner were to supply the machine with material and to mend the threads when they broke.

As these machines were made with a large number of spindles, it was found necessary to obtain suitable power for driving them. Arkwright's first factory was driven by horses, in the same fashion as small farmers still drive their thrashing-machines, the horses walking round and round in a circle turning a gin. When Arkwright put up a larger factory in Derbyshire, he utilized a water-wheel for supplying the necessary power, and owing to this fact the yarns spun there received the name of *water-twist*. This name has persisted up to the present day, but its meaning is not widely known. I remember asking an old manager in a weaving factory why the yarn was called "water-twist," and he said it must be that it was spun through water.

Arkwright's automatic machine made much more regular threads than Hargreaves' spinning-jenny, but both came into general use, and gave a great impulse to cotton manufacture. Although Arkwright had a very uphill fight for many years, his factories ultimately proved very profitable, and before his death in 1792 he had accumulated about half a million sterling.

These ingenious machines, however, could not make yarn nearly so fine as the Hindoo spinner could make with his simple wheel, and so all our fine muslins continued to come from India. When the English weavers tried to imitate these fine fabrics they found the yarns very rough and faulty. One weaver lad, Samuel Crompton, was very much annoyed at the imperfections of the yarn. His father had died while Sam was only a few years old, so the boy had to help his widowed mother at the loom. The boy often wished that he could get more regular yarn to work with, as he had a hobby of making fiddles, but was so hindered in his work by bad yarn that he could find little time to spare for his hobby. The young weaver formed some idea of a better method of spinning, and to enable him to buy material for his models without encroaching on the household income, he used to play the fiddle at the local theatre at night. It took all his spare time for five years to perfect his idea, and even then he was sometimes up all night. Crompton's machine was really an ingenious combination of the two former machines, with some additional improvements. In Crompton's machine the spindles were mounted on a travelling-carriage, hence its name the "mule-jenny." This machine was a great advance on the other two, as it could spin very much finer and more regular yarns.

It will be remembered that young Crompton's idea was to enable his household to spin more regular yarns, so that he might have more time for his hobby of fiddle-making. He feared that his machine might meet with the same fate as Hargreaves' jenny, so during one of the riots of weavers and spinners he took his machine to pieces and hid it. When he set it up again it was only for his own use, and he endeavoured to keep the fact of its existence a secret. However, the machine was well able to speak for itself; its productions were so far ahead of other yarns that everybody was surprised. The result was that everybody wanted to see the machine on which these yarns had been produced, but Crompton would not admit them to his house. Some of them climbed up ladders to see the machine through the window, and one fellow was found who had been hiding in the loft for several days, so that he might watch the machine at work.

Young Crompton's friends very foolishly advised him not to take out a patent for his invention, but to make known the principle of his machine to those manufacturers who would subscribe from a crown to a guinea.

Crompton parted with his invention in this manner for some fifty or sixty pounds. Others started large factories, in which the mule-jennies produced high-priced yarns at a much lower cost than Crompton could do in his small way. So he became discouraged and depressed.

Crompton's invention had given the Cotton Industry in this country an immense impetus. The duty paid upon the raw cotton brought into the country to be spun on his machines soon represented hundreds of thousands of pounds sterling per annum. Many millions of spindles were soon at work in Great Britain, and one of our greatest industries was firmly established.

The country could well afford to recompense Crompton for his wonderful invention, but when a grant of five thousand pounds was proposed in Parliament, one member suggested that a hundred pounds a year was "as much as the fellow could drink." Even the five thousand pounds which was given to poor Crompton scarcely paid the debts he owed in connection with business losses. He spent his last days in poverty, while his invention brought large fortunes to others, and at least three hundred thousand pounds per annum to the Chancellor of the Exchequer.

The complete method of preparing and spinning cotton, as practised in our modern factories, will be described in a later chapter on *Thread-making*. It will be of interest in the meantime to see how the invention of these spinning-machines led to the introduction of machinery for weaving cloth.

CHAPTER III

WEAVING BY MACHINERY

In the preceding chapter we have seen how the ingenious barber, Dick Arkwright, unlike the other inventors of spinning machinery, ultimately reaped some financial benefit from his labours. When he built a large factory in Derbyshire, and proved that his machinery could produce large quantities of yarn, one would have thought that all the manufacturers would rejoice. There would be no more enforced idleness of the weavers for want of weft yarn.

Perhaps it was only natural that some of the people should take a very pessimistic view of the matter. What would become of the poor hand-spinners, who could not keep pace with the capabilities of these inanimate machines? One hears very similar questions being asked even at the present time concerning the increase of machinery, but surely the more cheaply we can produce manufactured articles the better for mankind? Had the pessimists had their way our country would never have come to the forefront as it has done, nor should we have accumulated the wealth we now possess.

WEAVING BY MACHINERY

But even the manufacturers thought that this great advance in spinning was going to ruin them and their country in the following way: All the weavers in the country would not be able to weave up the great quantities of yarn which would be produced by these spinning-mills,* so the spinners would ship the surplus yarn to the Continent, where the weavers would produce cloth to compete with the home industry. We have the problem of "dumping" to deal with at the present day, but the case at that time was not so hopeless as was at first imagined, as we shall see from the following incidents.

At a country house in Derbyshire a number of gentlemen, while having an after-dinner smoke, discussed this vexed question. The discussion was, no doubt, a heated one, as some of those present were interested in the manufacturing concerns whose doom was so terribly prophesied. The recent erection of spinning-mills in the neighbourhood would, no doubt, intensify the feeling of alarm.

It so happened that a clergyman was present during the discussion, and he ventured to suggest that machinery might be invented to weave up the yarn into cloth as quickly as the spinning-machines could produce it. Of course, a clergyman is supposed to be utterly devoid of any proper thinking in connection with the secular business

* It may seem strange that we should speak of spinning and weaving factories as "mills." A mill is, properly speaking, a place or building in which the thrashing and grinding of corn is carried on. It so happened that some of the pioneer manufacturers utilized disused mills for the purposes of spinning, and so the name came to be used in connection with these industries.

of the world, and so the suggestions of this reverend gentleman were laughed out of court. One manufacturer told him he might as well tell Arkwright to grow the cloth ready-made; the idea of weaving by machinery was too ridiculous to anyone who had a knowledge of the operations required for weaving. The clergyman admitted frankly that he knew nothing about the process of weaving. But while he could conceive that the necessary motions were more complex than those required to spin yarn, he could not imagine that they were any more complex than the moves made when playing a game of chess. But why use chess as an analogy? Because at that very time (1784) there was being exhibited in London an automatic figure which could make all the variety of moves in a game of chess, just as though it were a human being.* Probably the manufacturers told the clergyman that he did not know what he was talking about, but he was convinced that there would some day be "weaving-Johnnies" just as there were already "spinning-Jennies."

We can picture the clergyman returning home feeling very much annoyed that the suggestion, which seemed to him so reasonable, should be so lightly scoffed at by those who ought to be able to appreciate it. The more he considered the matter, the more did he become convinced that a machine might be made to weave, and although he

* I am informed that this chess-playing automaton was ultimately discovered to be a trick. The figure, which sat at a solid table, had a boy inside. When it was opened to show that there was nothing within, he got into the table. And when the table was opened, he got back into the figure. How easily we are duped!

had no knowledge whatever of weaving, he determined to make an attempt to solve the problem.

One is surprised to learn that this clergyman—Dr. Cartwright, who lived in Derbyshire—had never seen a hand-loom at work. He seems to have known only that a number of threads called the *warp* were stretched lengthways in the loom, and that the weaver interwove the weft-threads with these, just as the good housewife darns the hole in a stocking by first laying threads across in one direction and then interweaving other threads across these. Dr. Cartwright would have saved himself a lot of trouble and expense had he only gone and watched a hand-loom weaver at work. However, we shall see later that this ingenious clergyman succeeded in making a practical machine which could weave cloth on its own account.

It will be of interest to see how weaving had reached even the simple stage at which it was when this clergyman took the matter in hand. We know that the ancients practised the art of weaving from the earliest times, but their methods were very similar to that of darning a hole in a stocking. They stretched a number of long threads, forming a *warp*, between two bamboo rods, and then darned or interwove these with other threads, called the *weft*. The Egyptians and Greeks hastened the process of weaving by introducing simple *healds*, by which the warp-threads might be opened to form a *shed* or passage, through which the weft-thread was passed by means of a long stick. It is obvious that this would be very much quicker than darning in the weft

WEAVING BY MACHINERY

The girl to the left is wheeling along a warp beam filled with yarn and ready for mounting in a loom. To the right there is a Jacquard loom with its perforated cards hanging over it. It is these cards which produce the elaborate designs in the cloth.

over one thread and under the next alternately. One heald would lift every alternate thread at the same time, and a weft-thread would be inserted; then a second heald

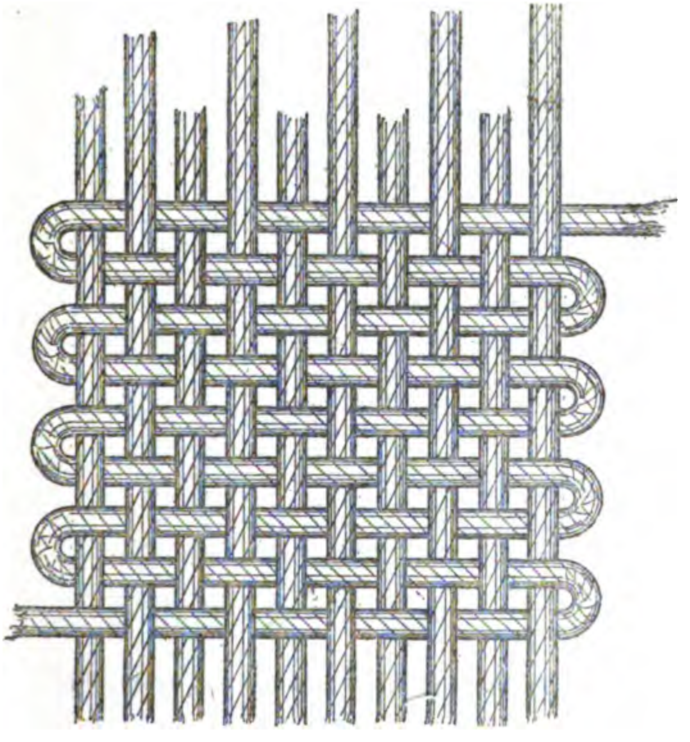


FIG. 2.—SHOWING THE WARP AND WEFT INTERLACING TO FORM PLAIN CLOTH.

would raise all the other warp-threads, and a second weft-thread would be passed into this shed, the result being as shown in this simple diagram (Fig. 2).

The primitive *healds*, referred to in the preceding paragraph, were simply loops of twine, each passing around a warp-thread, and supported by a wooden rod, as shown in Fig. 3.

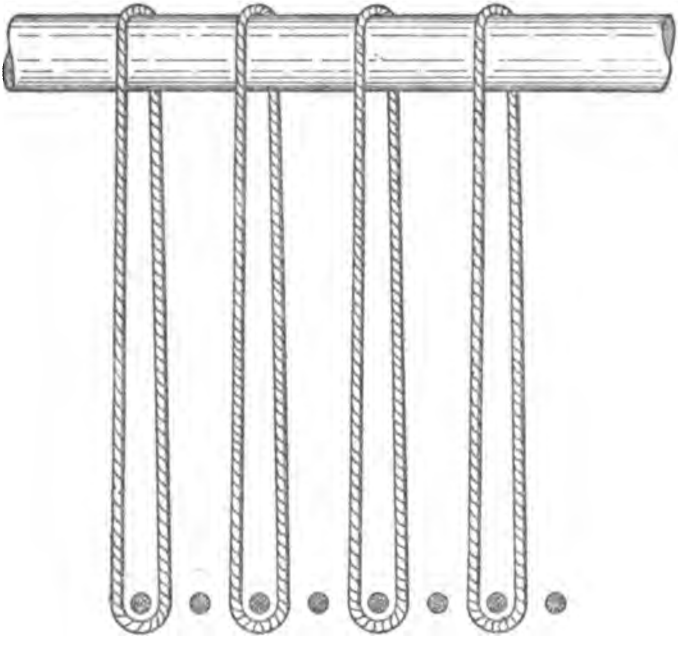


FIG. 3.—PRIMITIVE HEALD, OR HEDDLE, FOR RAISING WARP.

It will be observed in the above diagram that only every alternate warp-thread (represented by dots) passes through the loops hanging from this rod. The other warp-threads will pass through similar loops, attached to a second rod. It will be obvious that if one rod is lifted while the other remains down, an open shed will be formed, through which the weaver can pass his stick, carrying with it the end of his weft-thread. Having placed the weft-thread across the warp in the open shed, the weaver then uses the weft-stick to *beat up* the weft-thread into position. He then raises the other rod, thus lifting the alternate set of warp-threads, and repeats the process just described.

In the foregoing description of a primitive loom we have learnt the general principle of all weaving—first, a means of shedding the warp; then some plan of passing the weft through the open shed thus formed in the warp; and, finally, beating up the weft close to the last weft-thread interwoven. In this simple fashion man was able to weave what we call *plain cloth*, and we can have no stronger single cloth than this, in which the warp and weft-threads are interlocked as often as it is possible. Man soon found that he could vary the appearance of the cloth by interweaving the warp and weft in other ways. For instance, if he used three rods with loops (healds), he could lift every third thread, and leave the two intermediate threads down, producing a simple twilled effect, as represented in Fig. 4.

As the reader is supposed to have no intention of becoming a practical weaver, we need not trouble him with further detail. All we wish to note is that one cloth varies from another not only in the material of which it is made, but also in the manner in which its warp and weft are interlaced. The ancients succeeded in making very fancy fabrics; they introduced differently coloured weft-threads, and interwove those so that they formed definite designs. Some of the mummy-shirts to be seen in the Assyrian department of the British Museum are wonderful productions. But the weaver had to be an artist; he had to manipulate each thread separately, in order to produce

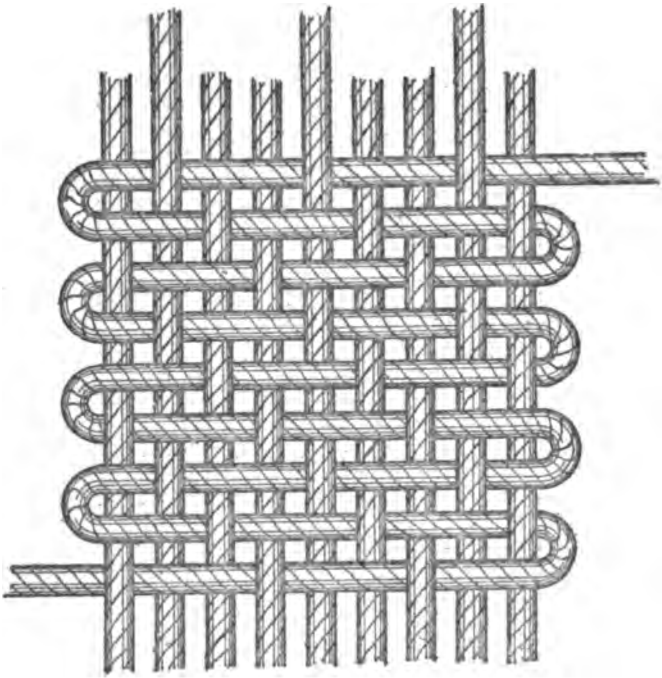


FIG. 4.—SHOWING THE WARP AND WEFT INTERLACING SO AS TO FORM A TWILLED FABRIC.

an elaborate design. He could not use healds, as he wanted each thread to come up or down, according to his fancy, and not in any regular rotation; he had to adopt the simple method of darning. Sometimes he would arrange his warp in healds, to produce a plain weave, and thus form the foundation of his fabric, while he darned in the colour-wefts as he went along. Some of the Indian shawls made in this fashion were most elaborate pieces of work, and, as we have seen in the opening chapter, these often took a lifetime to produce, while, at least on one occasion, three generations were required to produce a single shawl. It is obvious that with such slow means of production few could hope to possess these works of art. Modern manufacture has brought beautifully woven fabrics within the reach of all. We wish to see how this has come about.

First of all we find the Romans abandoning the stick for drawing the weft through the open shed in the warp. They introduced a hand *shuttle* which they could throw across the warp through the opened shed. The weaver threw the shuttle with one hand and caught it with the other. The weft-thread was then forced into position, or *beat up* by a wooden stick or *batten*. Other improvements gradually crept into the art of weaving, till we find, in the fourteenth century, looms not unlike the simple hand-loom which reigned supreme until the advent of the modern *power-loom*.

The practice of lifting the healds by hand to form the warp-shed had been abandoned long before this, and with the aid of strings and levers the weaver could raise the healds with his feet. At first the Eastern weaver merely inserted his great toe into a loop of twine, and pulling it down he raised a heald, but by introducing wooden treadles the healds could be raised more easily, the motion being the same as depressing the treadles or pedals of a pipe-organ. At the same time the simple heald gave place to a sort of double heald, which could both raise

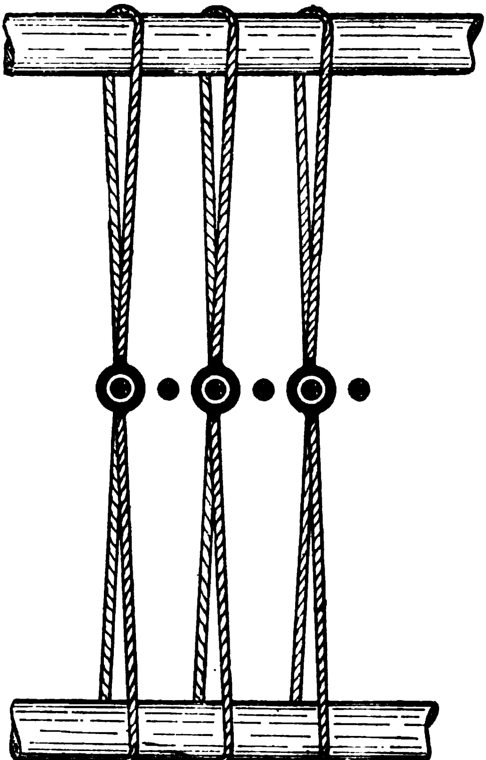


Fig. 5.—Double Heald, which can both Raise and Lower the Warp-Threads.

and lower the warp-threads. Sometimes this was made entirely of twine, fastened between two rods, but at other times a small metal eyelet was used for the warp-thread passing through, as shown in Fig. 5.

The general arrangement of the yarn in a loom will be understood from the following diagram (Fig. 6). This shows a side view of two sets of healds at work in a loom, one being raised and the other depressed, in order to form a clear open shed for the passage of the shuttle through the web.

It is apparent that if the healds are raised and depressed alternately the result will be plain cloth. But in order to

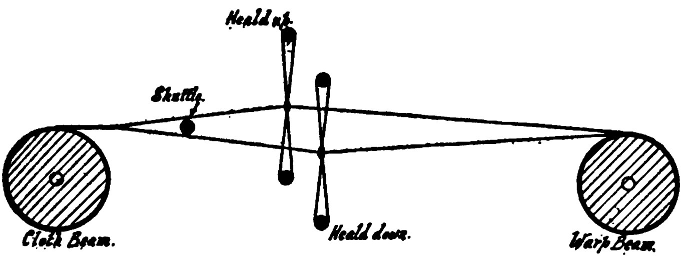


FIG. 6.—SIDE VIEW OF TWO SETS OF HEALDS AT WORK IN A LOOM.

get a variety of weave, the warp-threads are sometimes divided over a dozen sets of healds, and in this case the weaver requires to be as expert with his feet as the organist. Indeed, the operation of the treadles in producing a very fancy weave requires considerable skill.

I remember an old weaving instructor at one of our Technical Colleges telling me that on one occasion a certain Scottish Duchess sent word to the College that she was anxious to learn to weave the tartan of her own clan. My informant, who was a very plain-spoken Scottish weaver, was despatched to the castle, where a hand-loom had been erected. He addressed the Duchess as "Your ladyship," and he said: "Would your ladyship depress this treadle?" and so on, and so on. As the intricacy of the matter became apparent to the Duchess, she doubtless became confused in the required movements, for she was suddenly brought to book by the old Scotch weaver crying: "Tuts, wumman, can ye no lift yer fit?" Of course, what he intended to say was: "Would your ladyship please lift this foot?"

Long ago people had abandoned the primitive method of beating up the weft-threads into the cloth by means of a stick or batten, which had to be passed into the open shed of the warp and withdrawn at each weft-shot. This was necessarily a very slow process. It occurred to someone that a comb could be used to force up the weft-thread, the advantage in the comb being that it did not require to be inserted bodily into the open shed, as the single batten had. The teeth of the comb passed down between the warp-threads, and drove the weft-thread along in front of the teeth until the weft was hard up against the last shot in the cloth. Gradually the present system was evolved, and it will be obvious how an enormous amount of time was saved the weaver.

In mounting the warp into the loom, the threads, after being arranged in the healds, are entered through the spaces in a long steel comb, or *reed*, which extends right across the web. The reed is not like an ordinary comb, but more like a fine grating, for each tooth is fixed into a frame at both ends, as shown in Fig. 7.

The reed is hung in a rocking frame, and swings to and fro like a child's swing. When the weaver pulls this *lay*, or *slay*, forward the reed forces the weft-thread up into the cloth.

The old plan of throwing the shuttle through the web from one hand to the other has been replaced by what is called the *fly-shuttle*. This shuttle travels across the web on a small shelf or rack provided on the swinging lay.

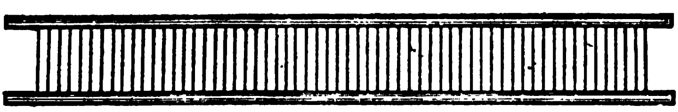


FIG. 7.—THE COMB, OR REED, WHICH BEATS UP THE WEFT-THREAD IN THE LOOM.

The weaver whips, or *picks*, the shuttle across from one side to the other in the manner well-known to all who have ever seen a loom at work.

It was the introduction of the fly-shuttle which upset the pre-existing division of labour between the weavers and the womenfolk who did the spinning of the weft-threads. This new method of throwing the shuttle enabled the weavers to get through their work so much quicker that they could not procure enough weft to keep them employed. No doubt there would be many grumblers at this dislocation of labour, but it was this very difficulty which brought about the invention of spinning machinery, as related in the preceding chapter.

All the operations of the hand-loom weaver are imitated by the modern power-loom. The rocking lay is swung to and fro by a simple crank on a revolving shaft, while the sudden forward motion of a wooden lever throws the shuttle across the loom with a speed sometimes equal to that of an express train.

The up-and-down movement of the weaver's feet is imitated by revolving eccentrics, or *cams*, as shown in Fig. 8.

When the hand-loom weaver had woven a few inches of cloth, he would stop and roll that on to his beam, and then proceed with another few inches, gradually building

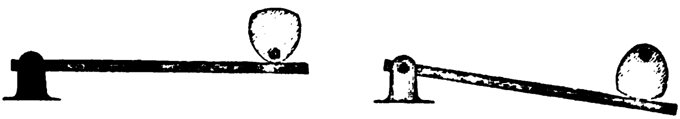


FIG. 8.—THESE REVOLVING CAMS TAKE THE PLACE OF THE WEAVER'S FEET, DEPRESSING THE TREADLES AS REQUIRED.

up a long length of continuous cloth. The power-loom does better than this, for it wastes no time stopping to roll up the cloth; it keeps rolling up the cloth at each stroke. The lay, when swinging forward, turns a train of wheels which feeds the cloth on to the beam at a regular pace.

In short, we have a perfectly automatic loom. As long as the necessary energy is supplied to turn its wheels, it will continue to weave cloth quite independently. The old hand-loom weaver had to give way to this modern machine, which could dispense with his services. But the loom has no brains, and it would go on weaving incessantly, no matter what might have happened to the warp and weft. Someone must see that the loom does not weave on after the warp or weft-threads are broken. A girl can take charge of several looms, and tie up the broken warp-threads. The loom informs her on its own account whenever the weft (shuttle-thread) breaks or has been all used up. Indeed, the loom refuses to weave if the weft-thread is absent.

It is interesting to watch a loom at work, and see it stop of its own accord. Possibly the weaver has her back turned to it at the moment; she may be mending a warp-thread in another loom, but this loom which we have seen stop waits patiently until it can be attended to. It looks quite uncanny to see the handle with which the weaver starts and stops the loom move over to the "off" position of its own accord. We need not trouble with the detail of this weft-stop motion further than to remark that when the weft-thread passes across the loom the thread supports a little light lever, which, if allowed to fall down, owing to the absence of the weft-thread, operates the stopping motion.

The old hand-loom weaver sometimes found his shuttle to stick on its way through the open shed of the warp. Of course he had the sense not to beat up his lay, or he would have burst the warp-threads at the place where the shuttle was caught. Although the power-loom is brainless, it will stop whenever a shuttle sticks in the web, and at the same time it will loosen the reed so that no blow falls upon the obstructing shuttle.

In looms for weaving fancy coloured fabrics, a number of shuttles, each containing a different colour, is used. The shuttle-boxes at the extremities of the lay have several divisions, one above another, and by raising and lowering the shuttle-boxes, the required colour can be brought into position for weaving. The movements of these shuttle-boxes are controlled mechanically.

In order to weave elaborate designs, such as we find upon our table-linen, some additional apparatus is required. This will be described in the succeeding chapter—*A Wonderful Automaton.*

CHAPTER IV

A WONDERFUL AUTOMATON

In the long ago we were all interested in everything which was *mechanical*. I refer to our days in the nursery, which seem long ago, no matter what age we have reached, although, if we concentrate our attention upon some event which made a deep impression upon the child mind, the nursery days may seem to have been only yesterday. I have most vivid recollections of receiving the present of a mechanical toy when I was five years of age. I see it clearly as it made its first journey round the nursery. One has only to take a walk through any of our stores at Christmas-time to see that mechanical toys are a great attraction to little folk, and, indeed, to many grown-up people too. Most of us have still an interest in anything mechanical, and our interest is much greater if we can see how the machine works.

In the Machinery Hall of any of our great Exhibitions one may see many people take a glance at some machine in motion, and then pass on without any seeming interest, whereas if they had a friend with them who could point out to them what enabled the machine to accomplish its task, they could not fail to be interested.

A WONDERFUL AUTOMATON

In the preceding chapter we have seen that a *plain power-loom* is an interesting automaton. If we take a look at a *fancy loom*, which weaves most intricate figured designs upon a plain foundation, we shall see that it is of far greater interest.

To watch such a loom at work, one would almost imagine that it really thought for itself. It is producing an exquisite design in the cloth, and is selecting the different shuttles as required. Sometimes it picks a shuttle from the drop-box at one side of the loom, and at other times it picks another shuttle which is lying in the box at the opposite side. One marvels at the memory the loom has, for although it has not used one particular colour for several minutes, it never forgets, in its onward rush, which side of the loom it left that shuttle at. Occasionally it happens that the loom wishes to bring in a few extra colours for which it has no room in its drop-box. It may possess only six shuttle-boxes, and the design being worked may require that some of the colours be changed occasionally. It would not be fair to leave this to the girl-weaver, for it would be almost impossible that she could catch the loom at the particular shot where the change is to be made, even if her memory should be good enough for the purpose. We can depend upon the loom, however.

Suppose we are watching one of these looms working away steadily, calling up one shuttle and then another, when, without any apparent cause, the loom stops. With the knowledge gained about the *plain* power-loom, we imagine the weft must have broken, but this is evidently not the case, for the weaver straightway picks up one of the extra shuttles, and changes it with one of the shuttles already in the loom. If you ask her how she knew which shuttle to change, and what colour, out of the variety beside her, was required, she will point to a number of little bits of coloured yarn suspended by cords at the front of the loom, and you will see that the colour required has been pulled up several inches by the cord to which it is attached, and at the same time the number of the box into which this has to go has been indicated. The weaver loses no time in doing what the loom tells her.

After we have witnessed several changes of extra shuttles we see the loom stop again. This time it rings an electric bell, which calls the attention of a man, who comes to the weaver's assistance, and changes the set of cards which has been passing through the machine over her loom (see photograph facing p. 50). While the man is making the change of cards, the weaver explains that she is weaving a fancy curtain, and that she has finished the *dado*, or deep border, at the base, and that the design changes at this point to the *filling* part, which is a different set of cards. Of course the observer noticed that it was the loom itself which informed the weaver and the card-shifter when the change had to be made. After seeing these incidents and examining the intricacy of the design produced, we marvel at the wonderful automaton. But who invented the mechanism capable of doing all this, which far surpasses the useful achievements of Dr. Cartwright?

If you should happen to ask any of the foremen or the mechanics in the factory who it was that invented the machine which stands over the loom, and which produces these exquisite designs, they will tell you the machine was invented by a Frenchman named Jacquard, and that the apparatus has been called a *Jacquard machine.* The manager may show you, on his office wall, a large picture of Joseph Marie Jacquard, and you may hear how he had to suffer for his invention, being treated at the hands of the mob very much in the same manner as poor Hargreaves was treated because of his spinning-jenny. Your admiration for Jacquard is increased when you learn that the machine in use to-day is the very same in principle as that invented originally by him more than a century ago. When one comes to look into the history of fancy weaving, however, one is surprised and disappointed to see how very little Jacquard really did invent. It is clear that two earlier inventors—Falcon and Vaucanson—had made and used machines almost identical with that of Jacquard. What really did happen seems to have been on this wise:

Jacquard, after many misfortunes in Lyons, had invented a machine for making net, and in connection with this he had received an appointment in the Conservatory of Arts and Manufacturers in Paris. It so happened that at this time the Government Works were weaving a magnificent shawl for Napoleon's wife—the Empress Josephine. Very costly methods were being employed in the production of this shawl, and it occurred to Jacquard that Vaucanson's machine would serve the same purpose, and provide a very much simpler method of pro-

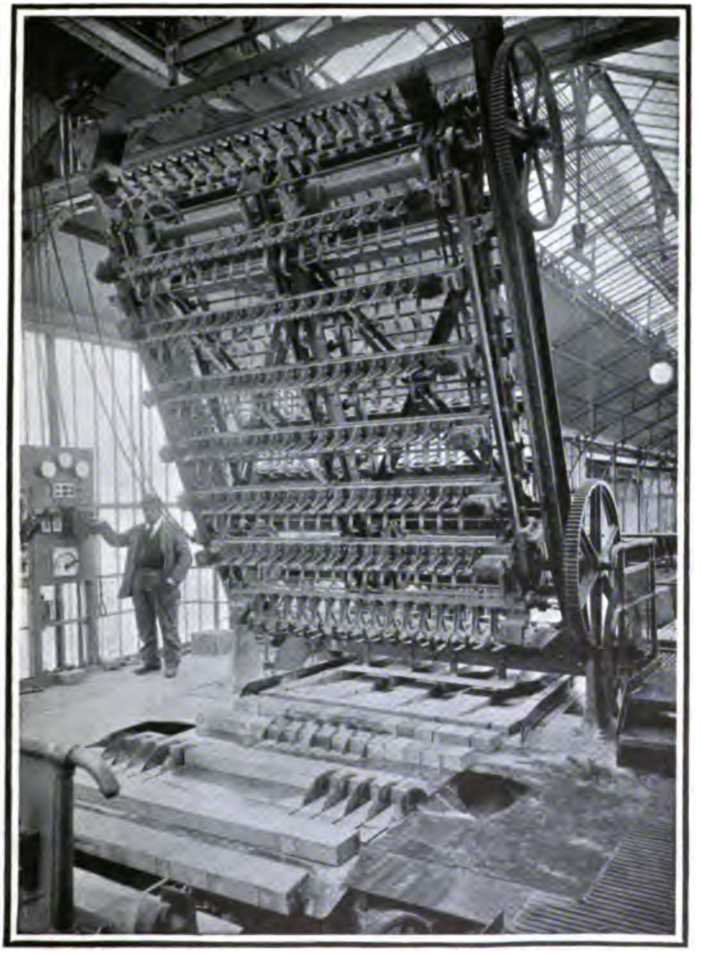


Photo by *Boyer, Paris*

CUTTING WOOD-PAVING BLOCKS

This large machine cuts no less than 240,000 blocks per day. The upper half of the machine has been raised in order to show the circular saws and the planks of wood entering the machine.

duction. This machine had an endless band of perforated paper, not unlike the music-rolls for a pianola or other musical automaton. Jacquard seems to have found this part of the machine unsatisfactory, so he adopted Falcon's idea of a chain of paper cards carried round by a square beam. The meaning of this will become clear when we take a look at the action of a Jacquard machine, but the point I desire to notice at present is that Jacquard does not deserve all the honour usually accorded him in connection with the invention of the machine which bears his name. On the other hand, there is no doubt that it was Jacquard who brought the machine into general use, and, as is so often the case, the real inventors are overlooked.

Jacquard returned to Lyons to introduce this machine into the silk trade, but the weavers were against "machines," and Jacquard's model was taken out into the public square and broken to pieces. It is gratifying, however, to find that, before Jacquard's death in 1835, this apparatus had not only made its way into every silk factory in France, but had come into use in Britain, Switzerland, Germany, Italy, and the United States. Its use was extended into the cotton and linen trades, and it is with this Jacquard machine that the designs upon our tablecloths are produced to-day. That Jacquard was a benefactor to modern manufacture is witnessed by a statue of him which now stands in the public square in Lyons, on that same spot where his machine was publicly destroyed.

There is a clear evolution of ideas leading up to the invention of the Jacquard machine, but it would be difficult for the uninstructed to follow it without going into a great deal of detail. In one of the intermediate stages of the evolution the warp was divided over a very large number of healds, so that the weaver could form a great variety of sheds for the shuttle to pass through. Such an arrangement could not be worked with treadles, but a boy was stationed at the side of the loom, and by drawing down a series of cords he opened the various warp-sheds.

By these draw-looms and their accompanying draw-boys the weavers could increase the intricacy of their designs, but they could not imitate the elaborate figures of animals and flowers which the ancients produced by their simple and tedious darning process. Before this could be done it would be necessary to control each warp-thread individually, and that is what the Jacquard machine does. Every warp-thread has the equivalent of a heald for itself; each warp-thread passing through a small metal eyelet, and each eyelet has a long cord connecting it to the Jacquard machine over the loom, the general arrangement of which is seen clearly in the illustration facing p. 50.

In the Jacquard machine each of the cords is capable of being pulled up by an upright hook, as represented in Fig. 9.

It will be observed that each upright passes through an eye or loop in a horizontal needle. The upright can slid up and down through this loop. Immediately under the top hooks of the uprights a long lifting bar extends, as indicated by the small cross-section of it in the diagrams. This lifting bar rises at every stroke of the loom, and carries with it all the uprights whose hooks are in their normal positions, raising the warp-threads in the loom beneath. If all the warp-threads were lifted, then no warp-shed would be formed, but it will be seen from Fig. 10 that, by pushing against the point of the horizontal needle, the other end of which presses against a small spiral spring, the needle tilts the upright hook out of reach of the lifting bar. It only remains to have some

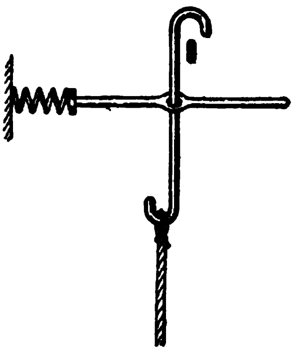


Fig. 9.

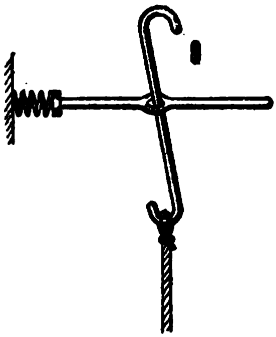


Fig. 10.

THIS SHOWS A JACQUARD UPRIGHT IN TWO POSITIONS.

In the first, its normal position, it will be caught by the lifting bar, while in the second position the horizontal needle has pushed it out of the way of the lifting-bar.

convenient means of pushing back the needles or leaving them alone as desired, and then we can control each warp-thread individually. This is accomplished by the perforated cards. If a needle is not to be pushed back, then a hole is punched opposite it. The needles are arranged close together in rows, so as to occupy as little space as possible.

A Jacquard machine for ordinary weaving has only about four hundred needles, but these give plenty of scope for a design, which may be repeated across the loom by tying the second four hundred threads to the same series of uprights, and so on.

The holes in the cards are punched out by a little machine, according to the design which is painted on specially ruled paper, and in many manufacturing districts card-cutting is a separate trade. Each card represents one shot of the shuttle across the loom, and it is not an uncommon thing to have as many as five thousand cards laced together to produce one repeat of a design. These sets of cards are hung up over the loom, as seen in the illustration of a weaving factory (p. 50).

If we use merely one shuttle to weave the fabric and form the design at the same time, we have what is called a *damask* cloth, such as the linen tablecloths we use in our homes. If we use a number of shuttles, we may form a plain cloth with coloured figures upon it, such as we often see in curtain materials; or, if we desire, we may weave a variety of coloured wefts to form the body of the fabric, such as in tapestries. However, what concerns us at present is the method of producing by automatic machinery these elaborate designs which formerly could not be produced without long and patient hand-labour.

Falcon and Vaucanson, of France, each invented a machine to do exactly what we have been considering; but it remained for Jacquard to bring the machine into everyday use.

It is seldom that a machine, invented so long ago as the Jacquard, can hold its own against all modern inventions. Some fifty years ago an electric Jacquard was invented, which dispensed with the somewhat bulky set of cards, these being replaced by a thin sheet of metal, upon the surface of which the design was painted with an insulating varnish. A set of fine needles, or *feelers*, rested upon this metal design-sheet, and when a feeler got in contact with the bare metal it allowed an electric current to pass to an electro-magnet which controlled the hook for lifting a warp-thread, and prevented it being lifted. The feelers resting upon varnished parts of the design plate received no current, and so the lifting hooks which they represented were left in position to be caught by the rising bars. These machines were not found satisfactory. It is true that when these electric Jacquards were tried in the middle of last century our knowledge of electricity was very deficient; but recent attempts on the same lines have failed to come into any serious competition with the simple machine introduced by Jacquard so long ago.

It will be understood that what we have been considering is only one particular branch of weaving; to go into further detail would not serve our present purpose, and might become wearisome. There is another kind of automaton, however, which is controlled by the Jacquard machine, and as the principle of the manufacturing process is totally different from what we have been considering, it will be of interest to go into the matter in the following chapter.

CHAPTER V

MAKING LACE CURTAINS BY THE MILE

THOSE of us who have grown up amidst the results of modern manufacture are apt to miss the romance of the subject. I wonder what our great-grandfathers would think if they could only return to time and space, and take a look into some of the shop-windows in our crowded thoroughfares. Probably they would pay very little heed to shop-windows, as long as motor-cars and electric tram-cars were moving about, impelled by some mysterious and hidden source of power. If we could get these folk of the "good old times" to look in at a draper's window, where they could see a pair of white Nottingham lace curtains, with elaborate design, marked for sale at one shilling per pair, they would be greatly surprised to learn that these could be made and sold for so very little.

If the old-time folk went into the shop and examined the fabric, their wonder would be greatly increased, for it would be apparent that these could not have been made in a weaving-loom, the threads being apparently twisted round each other to form the fabric and design. If they were to question the shopkeeper, I doubt if he could tell them any more than that "they were made by a

Nottingham lace-machine." Of course the shopkeeper has to make his living, and what concerns him most is the relation between the price at which he can buy the article, and the price at which he can sell it.

These lace curtains may be found in some room in almost every furnished house in Great Britain. Although they are usually called *Nottingham lace* curtains, they are made not only in Nottingham; there are lace factories now in Glasgow and other parts of Scotland.

If we examine the fabric of a lace curtain, our first idea may be that the threads have been "crotcheted" together in the same manner as ladies do fancy work. But to use ladies' crochet-work as an analogy for lace curtain-making would not be correct. Crochet-work is the making of one continuous thread into a fabric, whereas three different threads take part in forming the Nottingham lace fabric. It will be of interest to see how the modern lace-making machine has come about.

At many of the great Industrial Exhibitions held in recent times we have seen women and girls making lace by hand by twisting a number of threads together; and no doubt we did not envy these workers in their tedious task. One would certainly require to possess great patience as well as dexterity to be a hand lace-worker. Of course this is *real lace*, and costs a lot of money. We see sometimes in the newspaper reports of fashionable weddings that the bride's dress was adorned with lace which had been worn by her great-grandmother on the occasion of her own wedding, and so on. It is apparent that the ridiculously cheap lace curtain to which I have referred cannot be classed along with these fine productions of real lace, but some modern lace machines can turn out very good imitations of hand-made lace.

When the nuns in the fifteenth century made lace, they designed the patterns as they went along; their patterns were the carrying out of artistic thought. At a later period the lace-maker began to copy the work from patterns. To do so conveniently a little pillow was used, upon which the worker might fix her work along with the pattern to be copied. It was common practice when laying down this work to twist the threads round the lace pins and leave them hanging from the pillow. It has been suggested that the accidental intertwining of these threads, as they hung downwards, gave the first idea of that network which is the underlying principle of lace-making machines. Whether this be the case or not, it will be of interest to pay a visit, in imagination, to a modern lace factory.

What strikes one on entering is the great expanse of these machines, some measuring about forty-five feet in breadth, and producing cloth more than four hundred inches in width. The Jacquard machines, perched very high above the lace machines, attract our attention at once because of their great size. There are usually two Jacquard machines to each lace curtain machine, because in modern lace curtains there are generally two motions controlling each of the threads that form the pattern. One motion is governed by one Jacquard, and the other motion by the second Jacquard. Many of these Jacquard machines are made with sixteen hundred needles and uprights, so that in the two machines controlling the threads forming the lace we have no less than three thousand two hundred needles. The Jacquard machines, used with the ordinary weaving looms, with their few hundred needles, sink into insignificance before this lace Jacquard. But first of all let us pay attention to the arrangement of the yarn in the machine.

The warp-threads stand vertical in the lace machine, the warp-beam being very near the floor, and the cloth-beam about the height of the worker's head, thus giving a stretch of four or five feet of warp between these two beams. At first sight it looks as though it were a case of all warp and no weft, and, indeed, one might describe the arrangement quite fairly as such, for the threads which are going to produce the figuring are stretched in an upright position alongside the warp-threads.

Between three and four thousand threads are stretched from the warp-beam to the cloth-beam. These beams are made in sections, owing to the great breadth of the machine. The warp is the foundation upon which the lace curtain is built up, and beside each warp-thread there is what we might call the figuring-thread. This is termed the *spool-thread*, because each thread comes off a separate bobbin or spool at the back of the machine. These spool-threads are equal in number to the warp-threads, and take the place of the weft-threads in ordinary weaving.

In addition to these warp-threads and spool-threads we have yet a third set of threads, known as *brass bobbin-threads*, being so called because the thread is wound upon a brass bobbin. Looking at one of these, the stranger would never think of calling it a bobbin; it would seem more natural to speak of it as a very thin round flat disc. Nevertheless, it is a bobbin with two flanges, something like a pair of cymbals placed close together, only much flatter, and measuring about three inches in diameter. These brass bobbins are so narrow that from five to twenty bobbins, according to the gauge of the machine, will stand side by side in one inch of the machine. Even although the shuttles lie so close together, there is the necessary room for a warp and a spool-thread to pass between two neighbouring brass bobbins. These remarkably thin bobbins hold at each filling about one hundred and eighty yards of cotton thread. The purpose of this thread is to bind all the others together to form the fabric. There are, of course, as many of these bobbins as there are warp-threads, the number of which is the same as the spool-threads, as each brass bobbin is to look after one warp-thread and bind the neighbouring spool-threads to it.

The simple diagram (Fig. 11) on the opposite page will explain the nature of the fabric which is made. In the straight lines we see the warp-threads with the spool-threads crossing over from one warp-thread to the other, while the lighter brass bobbin-threads keep twisting round their respective warp-threads, thus binding the spool-thread and the warp-thread together.

If these cross-over movements, indicated in the diagram, were merely repeated, the result would be a solid cloth, provided the spool-threads made very frequent crossings. (*It will be understood that the threads are greatly magnified in the drawing.*) If, however, we can bind one spool-

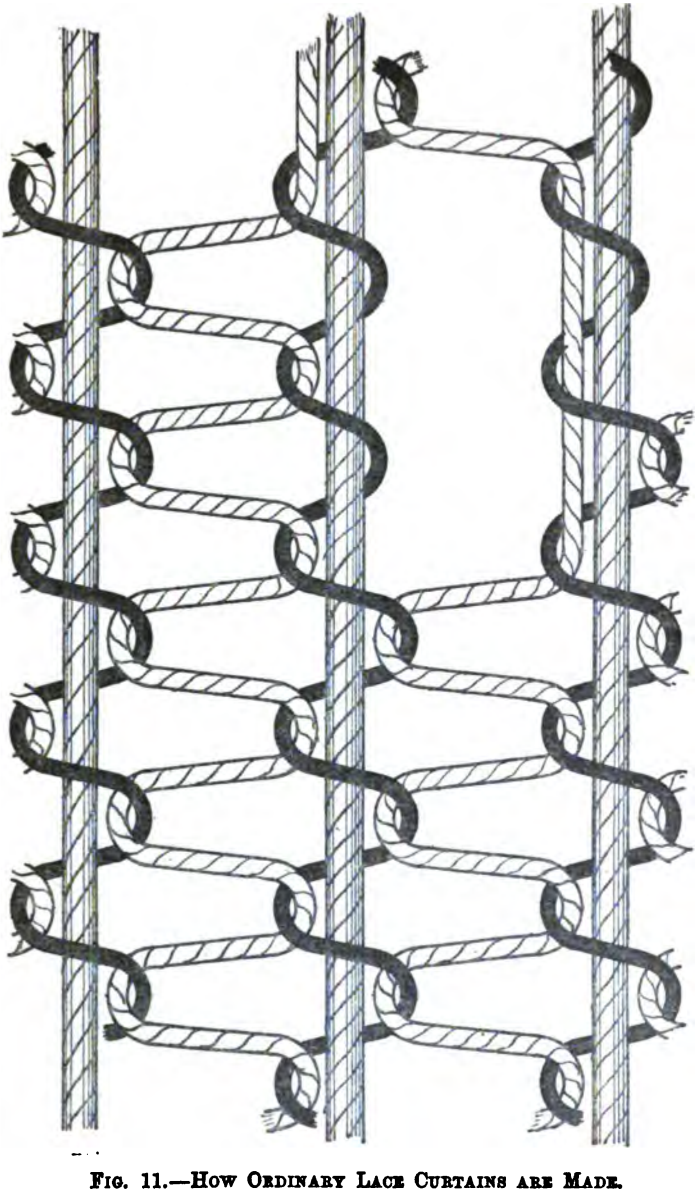


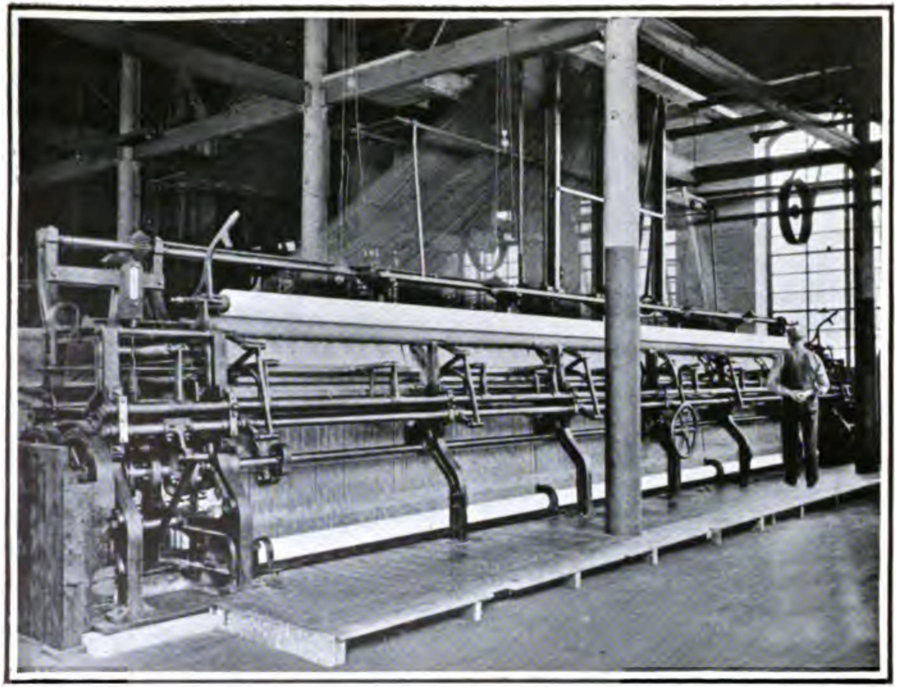
FIG. 11.—HOW ORDINARY LACE CURTAINS ARE MADE.

The straight rope-like lines represent the warp, while the finer rope-like lines represent the figuring-thread, which crosses from one warp-thread to its neighbour. The black lines twisting round the warp-threads represent the fine shuttle-thread which binds the figuring-threads to the warp-threads. Observe how a hole is formed in the right-hand top corner.

thread repeatedly to the same warp-thread, as indicated at the right-hand top corner of the diagram, we shall be able then to produce an empty space between the warp-threads. It is possible to do this by preventing the spool-thread from crossing over to its neighbouring warp-thread, and this is accomplished in the following manner:

There is a regular side-to-side motion given to all the spool-threads so that they will cross over at every stroke of the machine, but we can obstruct their passage. Between the neighbouring spool-threads there projects a little metal finger called a *jack*. These jacks, when in their normal position, will prevent all the spool-threads crossing over, but each individual jack can be pulled back by the Jacquard machine, in which case the spool-thread is allowed to cross over and become bound to the neighbouring warp-thread. That is how the design is produced in a lace curtain; filling up the spaces between the warp-threads at one place and leaving them open at another place. Then, of course, we can produce shading effects by partially filling up the space—say, by crossing the spool-thread only at every second or third stroke.

The brass bobbins are carried in very thin metal shuttles. These shuttles are merely frames for holding the brass bobbins, so that they may be made to slide through between the warp-threads as already indicated. These shuttles must, of course, pass through on one side of a warp and spool-thread and return on the other side of the same threads, in order to twist around and bind them together. There are two possible ways of doing this. The shuttles might pass through the warp and spool-threads, then move a little to



By permission of *Stevens & Williamson, Nottingham*

MAKING LACE CURTAINS BY THE MILE

The principle upon which lace curtains are made is totally different from ordinary weaving, and is explained in Chapter V.

one side and return on the other side of their warp-threads, which would remain stationary. On the other hand, the shuttles might be made to make a to-and-fro motion, and the warp and spool-threads would be given a small side-to-side motion, so that a warp and spool-thread would be to one side of its shuttle while it was passing inwards, and at the other side of the shuttle while it was passing outwards. The latter method is adopted, as it is much more easily obtained.

These simple side-to-side motions of the warp, and the larger but similar motions of the spool-threads, are conveniently obtained from simple cams or eccentrics at the end of the lace-machine, while the control of the obstructing jacks is under the care of the great Jacquard machines, cards being punched in the same manner as for ordinary weaving.

In place of a reed as in weaving, the lace-machine has two long bars with thick needle-points projecting, like a comb, between the warp-threads. These rise alternately at each stroke, and comb or beat up the threads into the cloth, after the jacks have decided which warp-ends the spool-threads are to be twisted to. There are other varieties of make, such as the spool-thread passing over two or more warp-ends, but sufficient has been described to give a general idea of how lace fabric is produced by machinery.

While the lace-machine may be four hundred inches wide, it goes without saying that there is no intention of making window curtains of that width. The width is divided off into as many single curtains as may be desired. In the cheaper makes as many as eight curtains will be made in the width of the machine. Any desired length may be made, and sufficient warp is provided on the beams to run between two and three thousand yards. The lengths are taken from the machines at about seventy yards, each curtain width is cut separate from its neighbour, and then the whole curtains are joined end to end, so that we have a continuous length of about thirteen miles of curtains from the one web. The total length of thread composing this length of fabric would be sufficient to stretch across the Atlantic from London to New York, and from there to the North Pole and back again, thence to China and through India to Africa. Indeed, it could stretch more than halfway round the earth.

Before the eight widths are joined end to end, they pass through the darning-room, where all broken ends are darned in by special sewing-machines. The thirteen-mile length of curtains is passed from this room through a hole in the wall to the bleaching tanks. It looks like a loose rope as it goes from one department to the other. After bleaching, the cloth is opened out and dried by passing through between heated rollers. Once more it is damped and starched by another machine, and then stretched out to its finished width, and finally dressed. It still continues its journey in one continuous length, from one flat to another, passing between rollers to keep it flat, until it is automatically delivered into the workroom, where the edges are cut out in the form of a scallop and then taped.

This cutting and binding with tape was done by hand originally, and one manufacturer informs me that he can remember when he had to pay as much as half a crown per pair of curtains to have them finished off in this substantial manner. With the aid of modern machines, which cut the scallop, fold the tape, and stitch it on, all in one operation, he can do the same thing now at a cost of twopence.

It will be understood that while I have referred to lace curtains selling retail at one shilling per pair, others may cost as much as thirty shillings per pair. Our interest, however, lies in the romance of the machinery producing these.

CHAPTER VI

EMBROIDERY DONE BY STEAM-POWER

Many years ago one of our weekly journals gave a cartoon of a then well-known divine, and entitled it "Preaching done by Steam-power." This was, of course, intended to describe the energy and vehemence with which the orator poured forth his sermons. There is no such suggestion intended by the title of this chapter. Indeed, if one steps from a power-loom weaving factory, with its almost deafening clatter of looms, and enters an embroidery factory, one is impressed with the idea that the embroidery machines are very gentle and quiet compared with weaving machinery.

From time immemorial embroidery has been associated with the fair sex. In the Old Testament Scriptures we find reference to "broidered work from Egypt." We also find King Solomon of old, when speaking of the industrious wife, saying: "She worketh beautiful vestments for herself." Nearly three thousand years have passed since these words were first written, and we find our gentlewomen still similarly employed. It is very seldom we find a man engaged in fancy needlework. Only two cases have come under my notice. One of these I came across in an old pamphlet in the British Museum

Library. It told of a sea-captain who employed all his spare time aboard ship embroidering fancy work.* It is evident that he was keenly interested in his curious hobby, for he sat up embroidering on one occasion long into the night, and when the lamp in his cabin failed in brightness, he went out and stood in the companion-way, working under a brighter lamp. He did not cease working until his fancy work was completed, but in the morning he was horrified to find that he had destroyed his colour-vision; he could no longer distinguish the colours in his needle-work.

The other case of which I happened to know is that of a present-day student at Oxford, who, when at his country home, will sit in the drawing-room working fancy embroidery, occasionally stopping to spread the work out on the floor that he may see the effects he is producing.

While it seems strange to find men engaged in fancy needlework, we are not surprised to find men in charge of the steam-power machinery which is producing embroidery work in large quantities. The machines are very large; you could not get one into an ordinary sized sitting-room. But while the machines themselves are very massive, their going parts are light, and move very smoothly. There are sometimes as many as four hundred needles in one machine, and these are arranged about one and a half inches apart from each other. Instead of making one long row of needles, they are placed in two rows, one at

* I have been informed that embroidery was a common pastime among sailors in the navy of Nelson's time, but I have not had an opportunity of corroborating this interesting statement.

some distance above the other, so that the two rows can work on two separate pieces of cloth. (See illustration opposite page 88.)

Although the mechanism required to operate the machine is somewhat complicated, the general principle upon which the machine works is easily understood. The machine has to adopt a different plan from that of the fair needlewoman. The latter can move her needle about to any part of the cloth she desires, but all the machine can do with its needles is to keep moving them forwards and backwards in the one position. It is obvious that as we cannot move the needles about we must move the cloth. The machine makes a stitch, and then we move the whole cloth into position for the needles to take a new stitch. But how can this be done conveniently?

The two pieces of cloth—each the full length of the machine—are stretched on a large frame which is suspended in the machine and so balanced with weights that it can be moved very easily in every direction. Then a pantagraph is attached to this cloth-frame, so that any movement of the free end of the pantagraph will give motion to the cloth. No doubt everyone has some idea of a pantagraph—a number of bars of wood or metal so connected together that the movement given to one point will be imitated on a different scale at another point. Pantagraphs are sometimes sold as playthings, and by tracing around the lines of a picture with a pointer fastened to one free end of the pantagraph, a pencil fixed to the other free end will produce a greatly enlarged drawing of the same picture. Of course, if the pointer and the pencil were made to change places, one could produce a small picture from a large one. This is the plan adopted in the embroidery machine.

In the accompanying illustration the man is seen with the pointer of the pantagraph in his hand, and as he moves it to and fro the cloth-frame imitates each movement, but on a much smaller scale. The machine is going to do all the sewing, but it is dependent upon the man placing the cloth in the required position for each stitch. The pantagrapher follows all the lines in the enlarged design, and the distance he has to move his hand is marked off by the designer. There is a certain amount of ingenuity required on the part of the machineman, for he must be able to find a complete path in tracing his design. If he were to go over some lines of the design twice, the machine would, of course, make the same mistake in the embroidery.

It will be observed that the embroidery machine is not so independent as the power-loom, in which the Jacquard machine relieves the weaver of all responsibility in producing the design. Machines have been made to replace the pantagraph man, but these have not come into general use, for reasons with which we need not trouble ourselves.

It is interesting to stand and watch an embroidery machine at work. We see the whole cloth move into position for each stitch. The cloth moves a little upwards or downwards, or to one side or the other. Gradually a geometrical figure or a conventional flower is built up on the cloth. But what is the machine really doing? It is not a simple case of pushing the needles into the cloth and then withdrawing them. That could be done by a simple crank motion; the machine has to perform more complex movements than that.

When the pantagrapher has moved the cloth into the required position, as many little fingers as there are needles come forward and hold the cloth firmly in position. Then the four hundred needles come forward and enter the cloth. It will be clear that the needles cannot pass right through the cloth and out at the other side, for they are fixed in a long metal bar. For this reason the needles have their eyes at their points, just as an ordinary sewing-machine needle has. The thread arrangement is also similar, there being four hundred separate bobbins of thread. The thread does not go direct from the bobbin to the needle, for reasons we shall see.

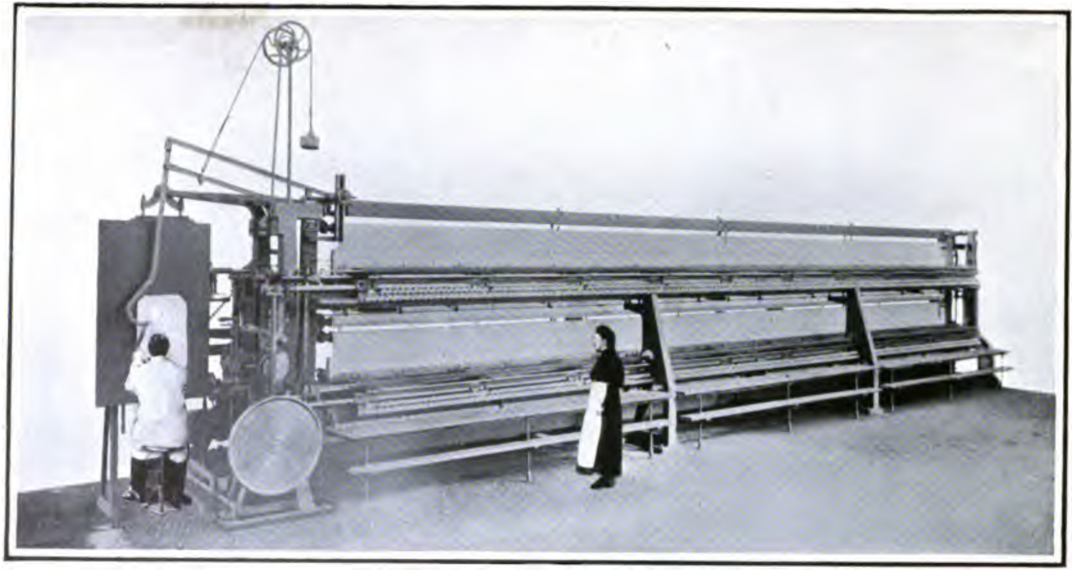
When the four hundred needles enter the cloth they perform an eccentric motion which throws the thread into a large loop, whereupon four hundred little metal shuttles dive through the loops, each carrying with it another thread, just as a weaving shuttle does. When the needles withdraw from the cloth, the shuttle-threads keep a hold of the embroidery-threads which the needles took through. It will be apparent that when the needles are throwing the loops, for the shuttles to pass through, the needles will require spare thread to form the loop, and then, when the shuttles have passed through, this spare thread must be drawn up tight at once. It is for that reason the embroidery-thread does not go direct from the bobbin to the needles. The thread passes over tension rollers and bars, which provide the required slackening and pulling up of the thread. Then the machine lifts its metal fingers off the cloth, and allows the pantagrapher to move the cloth into position for the succeeding stitch. All this is done in far less time than it takes to tell.

We have seen that the movements of the power embroidery machine are much more delicate than those of a noisy power-loom, and it is evident that unless all the motions are very accurately timed, the machine cannot do its work. Sometimes quite a trifling cause will completely upset the machine's work.

While the man is giving all his attention to the design, he has girl assistants watching that neither the embroidery-threads nor the shuttle-threads break. Any part of a design omitted by a broken thread has to be put in by hand later on in the darning-room. If the fabric upon which the embroidery is being done should be burst or torn by a broken needle in the machine, the darners have to reproduce the exact weave of the fabric, so that the cloth is as complete as before.

One might suppose that when a lady sees these great machines, with their host of needles, producing embroidery by the mile, she would refuse to spend more time in patiently embroidering one stitch at a time. Fortunately, this is not the result, for there is a charm about the personal work of a good needlewoman. The embroidery machine tackles the big requirements, and leaves the special requirements to the skilful and patient needlewoman.

In addition to the large embroidery machines, there is a number of accessory machines. One of the machines which is sure to attract our attention is quite a small one. There are several of them, but each one stands on a table by itself. It has two spindles, spinning round at a high speed, and on these it is busy winding very fine thread for the shuttles of the embroidery machines. What seems strange to us is that no one is attending to the machine; it seems to think for itself. As soon as a complete cocoon, or spool, is wound, the machine spindle upon which it has been wound stops revolving, and a metal finger comes forward and pushes the spool of thread along the spindle upon which it has been wound till it is very near the free end of the spindle. The finger then retires, and the spindle once more begins to revolve, and winds a second spool. When this spool is completed, the machine spindle again stops, and the metal finger pushes this spool forward. In doing this the second spool pushes the first one right off the spindle, but the thread is still continuous from one spool to the other. The first spool has fallen into a little metal thimble, where it is held for a moment while a pair of scissors cuts the connecting thread. The spool is then allowed to drop down, the thimble having no end, and the supporting finger being withdrawn by the machine. The finished spool, in falling, passes through a hole in the table into a large drawer, from which the shuttle-girls replenish their empty shuttles. Meantime, the spindle has commenced the same round of duties once more. Indeed, the whole process is done so quickly that there is no time lost. Each spindle works



EMBROIDERING BY STEAM-POWER

This machine works with over four hundred needles, and makes millions of stitches each day.

quite independently of the other; sometimes they may both be using their scissors at the same moment, or they may be engaged at quite different parts of the process.

As the shuttle-girls come and go, helping themselves to a supply of spools from the drawer, the machine pays no attention to them; it works on unceasingly, and if the factory is properly arranged, each machine will be able to supply the demand made upon it. How different from the time when the spools were made by small machines, each controlled by a little girl, fresh from school, who had so many other things to think about! Now a few of these high-speed automatic spooling engines replace a benchful of girls. All that the automatic machines require is that a girl takes a look round occasionally to see that they have plenty of thread to work with.

Of course there are many different methods of embroidering cloth; the foregoing is called Swiss embroidery work. No doubt we have all seen *tambouring* machines at work. They may be seen at almost every Industrial Exhibition, and their owners are always anxious to embroider your name or monogram upon a pocket-handkerchief.

The tambouring machine is very similar in appearance to a sewing machine, but has a handle beneath it, by which the worker operates the cloth feeder, moving the cloth from one side to the other, while it passes under the needle. If an elaborate design is desired, it must be traced or printed upon the work, so that the tambourer may follow it, but she is able to make simple designs at will as she goes along.

EMBROIDERY BY STEAM-POWER

Before the Swiss invented power-machines they had hand-machines working upon quite a different principle. In these the needles were passed right through the cloth and brought back at a different place, just as the needlewoman does. In general appearance these hand-machines were not unlike the power-machines. The pantagraph arrangement was the same, but the needles were held by pairs of little metal fingers on a travelling carriage. The man had not to attend to his pantagraph alone; he had to turn a crank at each stitch to impart the necessary movements to the machine. The front needle-carriage was moved in towards the cloth, the needles passed through it, and these were caught by similar pairs of metal fingers on a back carriage, which then travelled out with them, drawing the lengths of threads taut. As these back-carriage fingers closed upon the needles, the fingers on the front carriage opened. The travelling carriages imitate the movements of the needlewoman, passing the needle through the cloth and drawing the thread through. In order to make matters simpler for the machine, its needles were made with a point at both ends and the eye in the middle of the needle instead of being at one end. The needle could then be pushed through the cloth from the front and from the back without turning the needle.

After each stitch, which fastened some of the thread into the cloth, the carriages had to travel a little shorter distance as the threads became shorter, until finally the thread was too short to work with, when every needle had to be threaded afresh. For a long time this continual threading of needles was done entirely by hand, and was a source of worry to the man, unless he happened to have very expert girls. Later on a machine was invented which would thread any quantity of needles automatically, and leave them ready to be placed in the embroidery machine. Some very ingenious attempts have been made to adapt these hand-machines to go at high speed by power. I have seen such machines at work on the Continent, but the motions required to regulate the tension on the threads according to the length of each stitch made necessitates such delicate arrangements that one could not place them in the hands of the ordinary workman.

I have spoken of the hand-machine as a thing prior to the power-machine, but these two do not occupy the same relative positions as the hand-loom and the power-loom in the weaving industry. The hand-loom is practically ancient history, but there are still many thousands of hand-machines in the embroidery trade in Switzerland, for these produce a class of work which differs from that of the power-machine, whereas the power-loom exactly imitates the weave of the hand-loom and in many respects it is more regular.

CHAPTER VII

KNITTING BY MACHINERY

If it were a matter of surprise to some to find that the power-loom was the invention of a clergyman, it will be a further surprise to learn that the machine by which hosiery is made was invented also by a clergyman, of the Church of England.

The art of knitting cannot boast of the long ancestry possessed by the ancient arts of spinning and weaving. Indeed, knitting is usually referred to as of modern origin, but nowadays we are apt to picture all *modern* inventions as belonging to the nineteenth and the present century. Of course the art of hand-knitting is much older than the hosiery machine, but even hand-knitting does not seem to have been in existence before the beginning of the fifteenth century. That stockings were not common even in the first half of the sixteenth century is evident from the following historic records: "King Henry VIII. wore knitted silk Spanish hose"; and, with reference to his daughter, it is put on record that "Queen Elizabeth in the third year of her reign—that is, in 1561—received by her silk-woman a pair of black silk knitted stockins."

KNITTING BY MACHINERY

For some time it was only the very rich who could afford to wear stockings. The other people had to be content with bandages of cloth around their legs, while some would go bare-legged, as only the very poor do at the present time.

By the end of the sixteenth century the art of knitting seems to have spread throughout the country. It was at this time that our clerical friend, the Rev. William Lee, of Cambridge (England), came upon the scene. Exactly how Lee came to think of a machine for knitting is not quite clear. One story relates how Lee, while a student at Cambridge, married a young country girl, and, having no money or income, besides losing his scholarship through his marriage, he had to depend upon his wife's knitting to bring in an income. The story goes on to relate how Lee set about to make a machine which would relieve his wife of this constant toil. However interesting this and similar stories of Lee may be, they lack any authentic confirmation, and one loses faith in their reality when the writers add that Lee "became a man of considerable wealth." We know definitely from a petition presented to Cromwell by the stocking-knitters of London, at a time when all the facts were fresh in the minds of those people, that Lee did not meet with financial success, but died in poverty in Paris. It is very doubtful, indeed, if Lee was ever married.

The reason for Lee going to Paris was that he could get no royal protection from Queen Elizabeth nor from her successor, James I. of England. It so happened that King Henry IV. of France was anxious to encourage all useful industries, and hearing of Lee's invention, he invited the reverend gentleman to come to Paris and bring his machine and some workmen with him. No doubt Lee would have met with success under this royal protection but for the horrible assassination of the King. During the commotion and persecution which followed, seven of Lee's workmen fled to England, leaving two in Paris, who were still there when the petition referred to was presented to Cromwell. Poor Lee, however, did not long survive his adopted monarch, and, as was so often the case, the real inventor received nothing but misery in return for his invention. The whole civilized world owes Lee a debt for the introduction of so useful a machine. Some of Lee's apprentices were soon able to set the industry agoing in England.

Having seen the circumstances under which the stocking-frame came to be invented, our chief interest lies in seeing how the machine works and what has been accomplished by this clever automaton.

The art of knitting by hand, which is practised now merely as a useful pastime by the fair sex, is not very clear to "mere man," although some of the rising generation may gain more knowledge of the art, for when visiting a country school recently I found the boys employing their spare time in knitting. I doubt if any one of them will continue the practice till manhood, but it serves a present purpose in keeping them out of mischief while their teacher attends to other scholars.

There is one point which we must have observed in connection with knitting—that only one long continuous thread is used. If we have no recollections of assisting in the winding of wool from a hank to a round ball, we have, no doubt, seen the process. Our knowledge of the next process, however, may be somewhat hazy; we know that somehow or other, with the aid of two or more knitting wires, this long thread is gradually linked together to form a complete stocking or other knitted article. That the process is a constant repetition of certain definite movements is evident, for we have seen ladies absorbed in some interesting work of fiction while their fingers still kept busily knitting away.

Although there are many stories suggesting that Lee turned his attention to inventing because his fiancée jilted him, one could easily imagine, on the other hand, that the constant repetition of the same motions in knitting would suggest the possibility of these being undertaken by an automatic machine.

We need not trouble with a lesson in the art of knitting further than to notice the general principle of the process. If the knitter desires to make a flat piece of work, she requires only two knitting wires. She first of all forms a row of loops along the one wire, making the row equal to the width of the article she is about to make. Having done this in any way she finds most convenient, she then slips the point of the second wire through the loop last formed; then, making a new loop on the end of this second wire, she draws it through the last loop, which is now slipped off the first wire and rests suspended from the new loop on the second wire. This process is carried on loop after loop until the whole row is transferred to the second needle, whereupon the same routine is gone through once more.

An expert hand-knitter may form as many as one hundred loops, or stitches, per minute, but it would be difficult to keep this rate up for a whole day. Indeed, the average knitter could not produce one pair of stockings in less than two days. It is evident that the factory wages for this alone would amount to more than one pays in a retail store for a pair of woollen stockings.

It is difficult to see, at first, how a machine will be able to hasten the process of knitting to any very great extent, for it is evident that the loops cannot be formed in any wholesale fashion, as only one continuous thread is used, and each loop must be formed before the succeeding loop can be made. Lee's machine, however, was able to form the successive loops very much more quickly than the most expert hand-knitter, for instead of giving his machine two single wires, or needles, he gave it as many needles as there were to be loops.

Curiously enough, this clever automaton, the invention of a clergyman, had an important addition made to it by a Derbyshire farmer, Jedediah Strutt. It is of interest to note that it is this same enterprising farmer who is referred to at p. 43 as giving Arkwright financial assistance to complete his spinning machinery. Jedediah Strutt's pioneer work in these industries was so great that it was followed in the third generation by a peerage, his grandson being made the first Lord Belper. The Strutts built four magnificent mills at Belper.

Strutt's addition to Lee's stocking-frame was to enable it to produce those well-known ribs which run lengthwise down the leg of a stocking. These ribs, produced by the Derbyshire farmer, were called *Derby-ribs*, but the term is not common now.

The way in which the hand-knitter produces these ribs is as follows: She draws two loops through to the outside of the stocking, and the next two loops she draws through to the inside of the stocking, or she may vary the arrangement of the ribs by taking two loops to the outside and one only to the inside, and so on, producing the well-known ribbed effect.

We shall not trouble with the details of Lee's machine, as, though it is very extensively used in some factories, the general reader will find it easier to grasp the operations of machine-knitting from a description of the *latch* or *self-acting* needle-machine. This machine was invented by a framework knitter about the middle of last century, and it has proved a great success. Its needles were described originally as *tumbler needles*, because each needle has a little hinged tongue which, when in one position, closes the hooked part, or if allowed to tumble back falls against the straight stem of the needle, as shown in the accompanying diagrams.

The legend beneath the diagrams will explain the different positions. When the latch is opened fully, it lies partly within a groove on the stem of the needle, and when the latch is closed, by the previous loop sliding up the stem, the nose of the needle-hook lies within a spoon-like groove on the end of the latch. Fig. (i) shows the needle at its highest point, and Fig. (iv) at its lowest point.

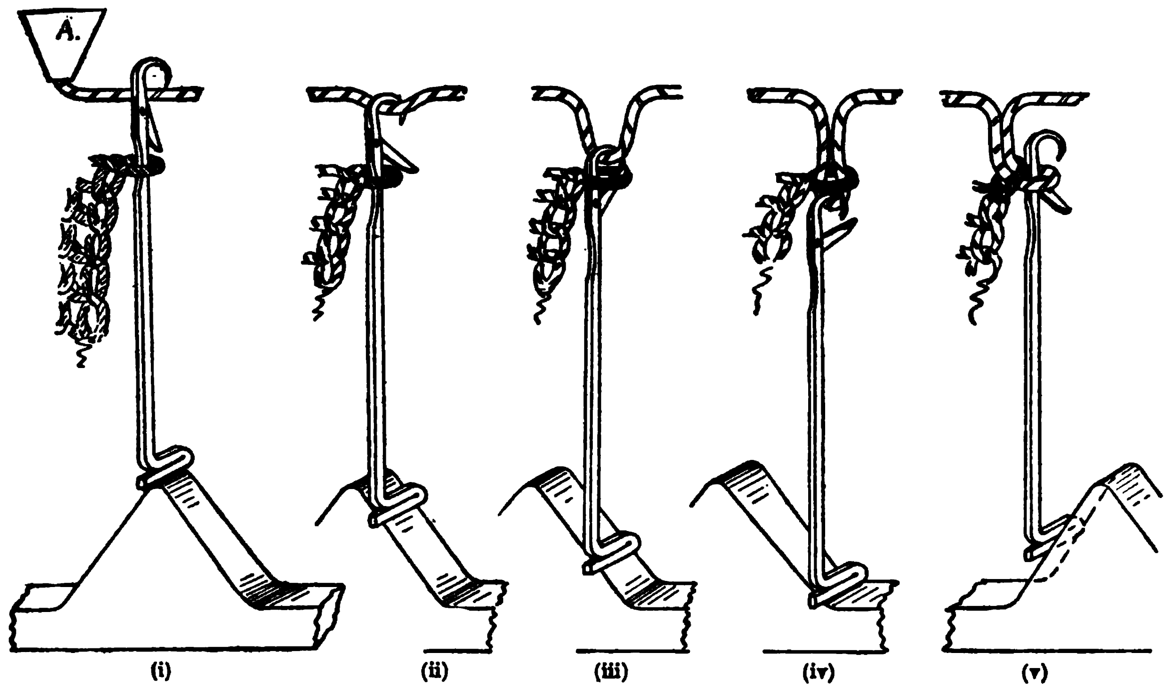


Fig. 12.—How Knitting is Done by Machinery.

(i) This shows a needle about to grip the thread which the guide A has just pulled across. Observe the previous loop on the stem of the needle suspending the work already done. (ii) As the pyramid-shaped cam moves to the left, the needle descends and takes the thread down with it, while the previous loop in sliding up the stem closes the small latch. (iii) As the needle descends farther, the previous loop is slipped over the new loop; (iv) whereupon the latch is free once more, and the new loop takes the place of the previous loop. (v) When the needle rises on the next stroke, we get back to the first position.

The needles rise up in succession as the thread approaches them. They are raised by means of the inverted V-shaped cam, travelling across the machine and passing under the little projections on the stems; these slide up the one side of the moving cam and down the other, as indicated in the diagram.

As we watch the machine at work, we see a travelling guide carrying the thread across the machine first in one direction, and then returning, while the needles keep rising in succession, each needle drawing a loop of the thread through the previous loop, which slips off the needle, and rests suspended by the new loop. The guides sweep the thread across the machine eighteen or more times in every minute, and the production is doubled by placing a second guide with another thread close behind the first guide, while a double cam causes the needles to rise a second time, so that whenever a needle has made one loop, and drawn it through the web, it is called upon to rise again and repeat the motion with the second thread. In this way a machine with six hundred needles at work will make over forty thousand loops every minute.

The various ribs are produced by the modern knitting-machine in the following manner: There are two rows of latch-needles, and these are placed at right angles to each other, as indicated in Fig. 13. One needle comes up from the right and one from the left, then another from the right, and so on.

Only every alternate pair of needles on the right and every alternate pair on the left will be used when a two and two rib is to be produced. Although these machines, with their straight rows of needles, are used nowadays mostly for flat-work, they can be and are largely used for making stockings which, when ribbed, are sewn up the back to form the tubular part for the leg and foot. The shaping of the flat pieces was arrived at by our friend the parson himself. Lee dropped and added needles at each side of the article as required, making the work

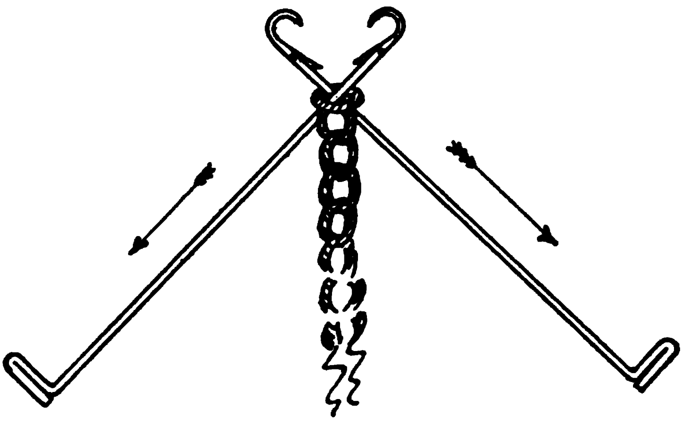


FIG. 18.—HOW DERBY-RIBS ARE KNITTED.

narrower or wider at such places. The hand-knitter succeeds in making a seamless ribbed stocking by arranging her work on three separate wires, placed so as to form a triangle; but, although the stocking looks triangular while in process, it is a good round sack when taken off the wires.

No matter what doubts we might have regarding the possibility of making a seamless ribbed stocking by machinery, the fact remains that a machine was made to accomplish this as early as 1816, but did not prove very successful until the introduction of the latch-needle. It is interesting to note that the inventor of this circular knitting-machine was the great engineer, Sir Mark Isambard Brunel, who built the Thames Tunnel in London, and whose son and partner, Isambard Kingdom Brunel, was the designer of the *Great Western*, one of the two first steamers to cross the Atlantic, arriving in New York on April 23, 1838. Brunel also designed the *Great Britain*, which was the first steamer to use a propeller at the stern, and another notable steamer of his designing was the *Great Eastern*, which for so long remained the largest steamer in the world.

We need not go into the details of Brunel's machine, for the same reason as we omitted a description of Lee's machine, and that is because these machines employed what are termed *bearded needles*, which are fixed in the machine, and are worked on a somewhat different principle from the latch-needle machines. It will be of more interest to see the working of a modern stocking-machine of the latch-needle type.

The principle of this circular stocking-machine is identical to the flat-work machine already described, but the needles are arranged in a complete circle, and the guide spins round the circle, carrying the thread to each needle in rapid succession. If the machine is being worked by hand, the operator has to shape the heel and foot by dropping certain needles. Then, by giving the machine a half-turn in one direction and back again, she gradually builds up the "baggy" part required, while the idle needles hold the last loops which were formed upon them, until called upon to join once more in the general dance.

In the most modern of those machines the movements are entirely automatic, the machine itself changing from the complete circular motion to the half travel to and fro, and at the same time dropping and adding needles as required to make the desired shape.

It is most interesting to watch these clever automata at work. They behave so well that one girl can undertake to overlook three, and on certain classes of work even six, machines. Each machine works independently, and as we come along it so happens that two of the machines are spinning round and round at a great speed, while the third machine is making the half revolution to and fro at a more leisurely pace. It will be understood that it is the guide which travels round the machine, while the latch-needles rise and fall in their fixed positions.

We are quite surprised when we see one of the machines changing from the one motion to the other. After continuing the half-turn motion for some time, the guide sets off again on its mad whirl, building up the leg of the stocking. We know that the leg part of a stocking is a fairly long straight sack, and one would imagine that we should have to wait a considerable time before we should see this machine change again to the heel part; but it seems no time till the machine is back again to its swinging to-and-fro motion, and we are more surprised when the manager informs us that the machine has made two "legs" in these few minutes. On looking at the pro-

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KNITTING BY MACHINERY

Here we see a busy hive of industry, some of the wonders of which are told in Chapter VII.

duction of the machine, we see that there is a regular rope of stockings, and that these are made toe to toe and leg to leg.

The girl operator, who is looking after three of these machines, could knit one stocking each day by the ordinary hand-knitting process, and even that would mean her fingers very hard at work manipulating the knitting-wires. By means of these machines she is able to produce about one hundred stockings every day.

There are rotary knitting-frames in use which can produce about one million loops or stitches in less than five minutes. Some of these have as many as six hundred needles, and four feeders revolving at a speed of about one hundred and twenty revolutions per minute. These machines produce plain, fine fabric, suitable generally for summer underwear.

The knitting-machines do not stop at plain and ribbed work; they will undertake to make those fancy tops used on men's and boys' knicker stockings, and they do this fancy work better than the hand-knitter does. These fancy tops are made on the flat-work machine, and the needles are controlled by a Jacquard arrangement, which throws the needles in or out of action according to the cards prepared for the particular design being produced. The use of the word *Jacquard* is perhaps a little misleading in connection with these knitting-machines, for there is really no Jacquard machine as in weaving, the cards in this case acting directly on the free ends of the needles, and pushing them up into position to be caught by the cam.

KNITTING BY MACHINERY

Having seen the general principle of knitting by machinery, we need not go into the further detail of making underwear, gloves, caps, and such-like. It is impossible to overestimate the great benefit which has been conferred upon man by the invention of knitting machinery, bringing warm knitted clothing practically within the reach of everyone.

CHAPTER VIII

WASHING CLOTHES BY MACHINERY

VERY few people have any correct idea of the methods adopted in a modern steam-laundry. The anxious housekeeper pictures the clothes being dragged this way and that way by unthinking machines, pounded by heavy battens, and crushed pell-mell through heavy wringers. Some have even thought that in a *steam*-laundry the clothes are exposed to the high temperature of steam, thus weakening the fabrics, while other people honestly believe that large quantities of hurtful chemicals play an important part in the cleansing process. However, for the most of careful housekeepers, the very suggestion of washing clothes by machinery conjures up all sorts of thoughtless ill-usage.

Of course the name *steam-laundry* was adopted to distinguish those laundries from the now fast disappearing hand-laundries, and the title was simply meant to indicate that the machinery was driven by steam-power, just as one occasionally sees such terms as steam-printers, and so forth.

How should people not have sailed along as their grandmothers did, and let hand-laundries continue to do the work? One answer is that our conditions of life are very different from theirs, and perhaps no better illustration can be given than a casual glance down one of the washing lists in a modern laundry. We see large stacks of goods to be despatched to hotels, steamships, etc. Here are three lines from one steamer's list: Two thousand seven hundred and eighty table-napkins, fifteen hundred towels, and one thousand and sixty bed-sheets. That is only one individual order, and not an exceptional one. A steamer may arrive in port on a Monday and sail again on the following Thursday, leaving only two clear days in port. The laundryman could not undertake such orders if he had to get workpeople to wash and dress the articles by hand; he can depend, however, upon his untiring machines.

It is the *machinery* in which we are interested, and so we need not trouble about the Receiving, Marking, and Sorting departments further than to note that all the multitude of articles has to be separated into lots of the one kind. This is not only a convenience, but is a necessity, as the different kinds of articles have to undergo different treatment.

It will be of interest to follow a dress-shirt from the time it enters the laundry until it leaves, for this is one of the articles which demand a good deal of attention. We go first of all to the *washing-house*, where we find rows of large metal drums, within each of which there is a large perforated cylinder revolving in a somewhat eccentric manner. It makes a few revolutions in one direction, then stops of its own accord and reverses its direction of rotation. It works away automatically, revolving first in one direction and then in the other, while within it lie the articles to be washed in soap and water. The to-and-fro revolutions of the drum exactly imitate the careful washerwoman's idea in turning the clothes over and over to insure the soap and water getting thoroughly through them. Indeed, the actual washing by these machines is very much easier upon them than the constant handling by the washerwoman. It should be noted that there are no moving parts within these perforated drums, but merely a few ribs fixed to the inside surface of the drum to prevent the clothes slipping, and to insure the continual turning over of the articles, while the supply of cold and hot water is controlled from the outside.

The hand-washerwoman would then put her washing through a *wringer*, but the steam-laundry treats the articles much more gently. They are placed in a *hydro-extractor*, which, as its name implies, is to extract the water from the articles. Sometimes when a man has been caught in the rain, he takes off his overcoat, and, giving it a quick movement or shake, he succeeds in dislodging a good deal of the water from it. The laundryman's method is even more gentle. We might demonstrate the principle of his machine in a very simple way. We give a boy a very wet article to hold in his hand, and, of course, a good deal of water drips out of the article; but if we get the boy to turn quickly round and round, like a *merry-go-round* at a country fair, the wet article taking the place of the flying horses, we should find the water to be driven out of the article much quicker while the boy swings it around. The quicker the boy could turn, the more water would be forced out; but his speed and his endurance would be very limited. Needless to say, the laundryman does not seek the services of boys for this purpose, but he adopts the same principle.

He takes a fixed metal drum, within which another perforated drum is very accurately balanced, somewhat like a boy's spinning-top. This drum can spin round upon its axis, and our chief interest lies in the great speed at which it is capable of being revolved. We are shown an empty drum being set in motion, and a very few revolutions blot out all the perforations from our vision. In a few moments we hear a deep humming sound, which gradually rises in pitch till quite a high note is sounding. The machine, when empty, is a veritable siren. No doubt we have schoolday recollections of sirens which were composed of revolving plates with perforations in them. When this huge siren reaches a certain note, the manager informs us that it is now running at top speed, and we notice that it now continues one steady note. Of course this happens only when the drum is empty, for when in use the clothes cover up the holes in the drum, and prevent the air rushing freely through.

When we are informed that the speed of this particular hydro-extractor is eleven hundred revolutions per minute, it is difficult for the amateur to realize what this means, as he has no definite rate of revolution with which he may compare it. A simple calculation shows us that the edge of the drum is travelling around at a speed far greater than that of an express train. If we could get a house-fly to cling on to the edge of the drum as it revolved at full speed, the little passenger would be travelling on this *merry-go-round* at a rate of one hundred and twenty-five miles per hour; but what the thoughts of the giddy fly would be we cannot imagine.

The articles leave the hydro-extractor in a similar condition of dryness or dampness as they would be had the washerwoman put them through the much rougher process of wringing. In the present case it will be observed that the articles were never handled except in putting them into and withdrawing them from the hydro-extractor. What the washerwoman wants now is warm sunshine and a good breeze blowing; these make an ideal day for her. The laundryman must be independent of the elements, and he has such quantities of stuff to dry that he must make things move along a little faster than Nature would do. His "washing-green" is a large drying-chamber, for which he prepares plenty of nice warm air, and by means of numerous air-propellers he produces just the right amount of breeze most advantageous to the drying of the clothes, so that he has one continual ideal drying day.

In this one respect the laundrymaid loses the romance attached to the washing-green, where, according to nursery legend, she runs the risk of attack by some historic blackbird. However, she has plenty of compensating advantages, for she has not to tramp about from one clothes-line to another; she merely stands at the entrance to the drying-chamber, while the clothes-lines very conveniently come in turn to where she stands. These lines are a pair of very quickly revolving brushes do this very expeditiously.

We find that all the plainer articles, which require no starch, get through the laundry very much quicker—a thorough washing as before, a race around in the hydro-extractor, and then a walk through between a series of rollers. But how can a roller imitate the sliding motion of the household iron? The laundryman really reverses matters entirely. His hot iron is stationary, and is composed of a very large, hot, copper plate, occupying a space of about ten feet by six feet. Four long rollers are placed one in front of the other upon this hot plate. There is some space between the rollers, and here the hot plate rises up in a "hillock" so that as much of the hot plate as possible is brought in contact with the surface of the rollers. The rollers are driven round by power, and a row of girls standing along the front of the machine place the articles beneath the first great roller, which presses the article against the hot ironing-plate. It will be observed that it is the article being ironed which is moved, and not the iron, which remains stationary. The first roller passes the articles on to the second and similar roller, and so on until the last roller delivers the finished articles to a row of girls ready to receive them.

We need not trouble with further detail, except to remark that table-linen and such-like, where starch is used, cannot be passed through these automatic ironing-machines as the starch would cause the articles to cling to the first roller. These articles have to be dealt with by one large roller working on a hot plate.

WASHING CLOTHES BY MACHINERY

We leave the modern steam-laundry convinced by our own eyes that the treatment given to the articles is in reality a very gentle one, and that the ideas of the general housekeeper have been erroneously formed.

The true romance in connection with the washing of clothes by machinery would be thoroughly appreciated by one of those weary toilers who worked under conditions which, less than twenty years ago, were described as "heavy and exhausting," while cases of women fainting at their work from sheer exhaustion were reported to the Home Secretary as recently as 1891. To-day one sees the workers leaving a modern laundry with bright faces, and well able to enjoy an evening's recreation, or even a continuation class in dressmaking or cooking at the local school.

CHAPTER IX

HOW WE CAME TO HAVE SEWING-MACHINES

POSSIBLY some of us who have grown up have thought the household sewing-machine to be a sort of stupid thing when we have been called to the rescue on some rare occasion when the machine refused to do its regular work. Of course it was really ourselves who were stupid in not knowing where the trouble lay, and, no doubt, if the machine could have spoken, a single word would have enabled us to put matters right. But only an inquisitive schoolboy ever troubles to turn up the machine and see how the business works. One crank moving a lever to and fro causes the shuttle to pass very close to the needle at the moment it dips down through the base, or bed-plate, of the machine. The needle-bar's motion is derived also from a crank on a revolving shaft. We see that there are two separate threads at work; that the needle forms a loop with one thread, while the shuttle carries the other thread through this loop, thus locking it in position.

A sewing-machine is part of the furnishing of a well-ordered house, and we have become so familiar with its presence that we scarcely stop to think it strange that we should have introduced machinery into our homes.

Our first interest is to see how the idea of sewing by machinery came about. There is no doubt that it was the constant repetition of the same motion required to form one stitch after another that made people think it possible that a machine might do the work. Many inventors tried to make machines that would imitate the different movements of the needlewoman's fingers. One great difficulty that they had to contend with was the fact that as each stitch was put in the cloth the thread became shorter, so that the travel of the needle must vary accordingly. All such attempts proved unworkable.

What seems to have led to the first practical sewing-machine was the difficulty of sewing leather by hand, for we find an English patent taken out by Thomas Saint, in 1790, for the purpose of sewing leather. Curiously enough, the printed specification of this patent refers only to a means of japanning leather, but in an appendix to *Abridgments of Patents*, printed at a much later date, a short description of the sewing-machine is given by the Patent Office. The machine worked in the following manner:

A sharp awl descended and pierced a hole in the leather, then a spindle turned a projecting finger so that it crossed the hole, carrying the thread with it. A little fork then descended and pressed the thread down through the hole, one end of the thread being held fast above, so that a loop was formed on the underside. This loop was caught by a reciprocating hook, while a feeder moved the leather forward the distance of one stitch, whereupon another hole was pierced and another loop was formed. This second loop descended within the first loop, which slipped off the hook as it caught the second loop, thus linking one loop within the other. In this way a regular chain of loops was formed, and the ordinary *chain-stitch* of to-day was made. It will be observed that the needle had no eye; it had a forked end for depressing the thread. Although this machine did not come into general use, it is of special interest because its inventor came very near to the opening up of that industry which has proved a great mine of wealth to others.

The next inventor of interest was a French tailor, who formed quite an independent idea in 1838. He used a hooked needle such as ladies use for crochet-work, and he kept his bobbin of thread underneath the cloth. The crochet-needle descended through the cloth, caught the thread, and pulled up a loop on to the surface of the cloth. At the next stroke the crochet-needle descended through the previously formed loop. While this motion was repeated, the cloth was fed forward a short distance at each stroke, the needle always descending through the loop immediately preceding it. In this manner a chain of loops was formed similar to the chain-stitch made by Saint's leather-sewing machine. It will be observed that the principle of these two inventions was the same. In the one case the loop of thread was pushed down from above, while in the other case the loop was pulled up through the cloth.

After constructing a very clumsy machine, in which almost all the parts were made of wood, this French tailor, Thimonnier, succeeded in obtaining money to equip a small factory in Paris. So well did he succeed that in a very short time he had eighty machines at work making army clothing. A mob of infuriated tailors attacked the place, completely wrecking the machines, and nearly killing the inventor himself. Poor Thimonnier made another start, but in this he met with little success.

News did not travel fast in these days, and I doubt if our American cousins knew anything about these attempts to sew by machinery. However, we find that about 1834, a date coming between the two inventions just described, Walter Hunt, of New York, made the first attempt at producing a fast *lock-stitch*. The *chain-stitch* work is apt to *run*, or come out. Hunt's idea was to use two separate threads, one below the cloth and the other coming down through the cloth and interlocking with the other. He used a curved needle with an eye near its point, so that on forming a loop below the cloth a little shuttle might pass through the loop, carrying the second thread with it. Hunt did not patent his idea at the time, and when he endeavoured to take out a patent some nineteen years later it was refused on the ground of abandonment.

In the interim, another American had got on to similar lines, and evidently without knowing of Hunt's earlier attempts. The story is an interesting one. A young mechanic in Boston, Elias Howe by name, overheard a conversation between his master and a wealthy gentleman who chanced to call at the mechanic's place of business. What Howe overheard was a very emphatic statement that a great fortune awaited the man who should invent a machine that could sew. The idea became fixed in Howe's mind, and he set about trying to make plans by which this might be accomplished. His first idea was to imitate the movements of his wife's hand when sewing. It is generally stated that Howe was in poverty, and sought to invent a machine to save his poor wife from the constant toil of sewing for a living. Possibly there has been some confusion between Howe and Lee, who invented the knitting-machine, as related in the preceding chapter. In any case, it seems clear that there has been some misunderstanding, for Howe was in regular employment when he set about endeavouring to make a sewing-machine, and it was through his desperate efforts to arrive at a means of carrying out his idea that Howe, like many another honest inventor, became poor. Indeed, poor Howe would have had to abandon his idea altogether, in order to secure a living, had he not fallen in with an old school friend named Fisher, who had come to possess some money. This friend took Howe and his family to board free of payment in his own home, giving Howe the garret as a workshop, and undertaking to provide tools and materials so that Howe might work out his idea. The agreement was that Howe should give Fisher one half of any profits which might arise from the invention.

Howe was an enthusiast, and he devoted himself to his work till he produced a machine which could sew a seam. He soon satisfied his benefactor that the machine was reliable, for he sewed all the seams in two suits of clothes, one for Mr. Fisher and one for his own use. This first

TWO OF THE FIRST SEWING-MACHINES

The upper photograph is of Elias Howe's pioneer machine, while the lower photograph is of Singer's early machine, the general formation of which has not altered very greatly. These early machines are preserved in New York.

machine of Howe's had a curved needle, with an eye near its point, and the action of the needle was not unlike that of a pickaxe. With the aid of a shuttle beneath the cloth, it formed a lock-stitch in the manner already described. The principle was identical with that of Hunt's, and yet Howe produced his machine quite independently.

We can imagine Howe, the enthusiast, patenting his machine, and then hastening to make it public, and we can sympathize with him when he found that its exhibition only gave amusement to those who examined it. It was looked upon as a mere curiosity. But Howe had plenty of confidence in the machine. He challenged any five sewers to do as much work as his one machine. This bold challenge was accepted, and five of the most expert needlewomen in a large factory were selected for the trial. Ten garments were cut, each garment being exactly alike, and five of these were given to the machine, while each of the sewers took one of the other five. The race was begun, and anyone watching these experts would have thought the machine was undertaking an impossible task in proposing to sew five times as quick as one of these sewers. But before these experts had about one half of their garments done the machine cried a halt, having completed the whole of its similar task.

One would have expected an immediate demand for Howe's machines, but prejudice was too great. The tailors were up in arms against the introduction of machinery—a foolish spirit which, however, is not dead to-day, as will be seen from the following incident:

A few years ago I was lecturing on the subject of *Electricity* to a large audience of the deaf and dumb in one of our industrial centres. In order to show the audience an electric motor at work, I connected it to a household sewing-machine. Placing the motor and machine at one end of the lecture-table, I went to the other end and switched on the current to the motor, whereupon the sewing-machine was seen to sew a length of muslin. At this point there was some disturbance in the front of the area, and I saw a lame man shaking his crutch and his fist at the secretary, who was acting as my interpreter. The secretary explained to me that this man said he was a tailor, and that this machine would deprive him and his mates of their livelihood. I asked the secretary to point out to the lame mute that the electric motor was merely supplying the necessary power to drive the machine to save the tailors' legs, and that the machinist would still be required as at present.

Returning to our narrative of Elias Howe, we find that the opposition of the American tailors was so great that it was hopeless to get his machines introduced in that country. And so Howe's brother Amasa took out a steerage passage for England, carrying with him the rejected automaton. One might think that Elias Howe should have gone himself, but we must remember that a journey of this kind was a much more serious undertaking in those days, and Elias Howe had a wife and family to support, while we may presume that his brother was a bachelor. There may have been some feeling that Elias should wait and look after the interests of his own patent, although there did not seem to be much fear of any attempted rivalry.

However, Amasa reached London, and he was successful in getting a corset manufacturer in Cheapside to take an interest in the new machine. This manufacturer—William Thomas—offered Howe the sum of two hundred and fifty pounds for the English rights, on condition that the inventor would come over and adapt the machines to do the necessary work. We find William Thomas applied for the patent in his own name, stating in the specification that the invention had been "communicated by a foreigner residing abroad."

Elias Howe came over and worked with William Thomas, who paid him a weekly wage. Everything seems to have gone well, and Howe got his wife and family to cross the Atlantic; but after the machines were fitted up Thomas insisted on Howe waiting on to repair the machines. This gave rise to a quarrel, and Howe was dismissed.

Howe seems to have turned his attention to inventing sewing-machines once more, but how he was going to steer clear of the patent owned by Thomas it is difficult to see. However, poor Howe got into money difficulties, and as he saw no hope of bettering himself in England, he sent his wife and family home while he could find money to do so. He remained himself, evidently to try and complete a machine he was inventing, but he was soon in such straits that he had to pawn his American patent rights to raise sufficient money to take him home.

When Howe arrived in America he found several men busy making sewing-machines, and among these there was one real enthusiast—Isaac Singer. Howe declared that his patent rights covered all these machines, and having got financial help to enable him to redeem his pledged patent from England, he engaged lawyers to thrash out the case in the American Law Courts. Ultimately it was decided that the other makers should pay a royalty to Howe on each machine they made. This brought a fortune of two million dollars to Howe during the time for which his patent held good. The French honoured Howe by decorating him with the *Cross of the Legion of Honour*; so Elias Howe was rewarded in some measure for all his past hardships and devoted exertions in overcoming the difficulties of sewing by machinery. Many other inventors followed, but the most enterprising of all was Isaac Singer, the founder of the great business of which we shall read in the following chapter.

CHAPTER X

SEWING-MACHINES MADE BY MACHINERY

In the preceding chapter we have seen how Isaac Singer became an enthusiast in the making of sewing-machines, and no better monuments of his ingenuity could exist than those gigantic factories engaged at the present time in making sewing-machines by automatic machinery.

One of these huge Singer factories has been erected on the River Clyde a few miles below Glasgow, and through the courtesy of the management I am able to give the reader an insight into this great modern manufactory.

On entering the vast yards surrounding the works one is surprised at the enormous extent of timber stacks. Indeed, one might think that the business of the firm was that of timber merchants. For what is all this timber to be used? It is quite evident that it cannot be for the beautifully polished table-tops which form the only wooden part in connection with a sewing-machine. It comes as a surprise when we are informed that the whole of this timber is required for the making of packing-cases for despatching sewing-machines to all parts of the world.

In another part of the great yards we find a regiment of stacks of pig-iron, all of which is to leave the works in the form of sewing-machines. But the going parts of the machine are not made of cast iron; they are made

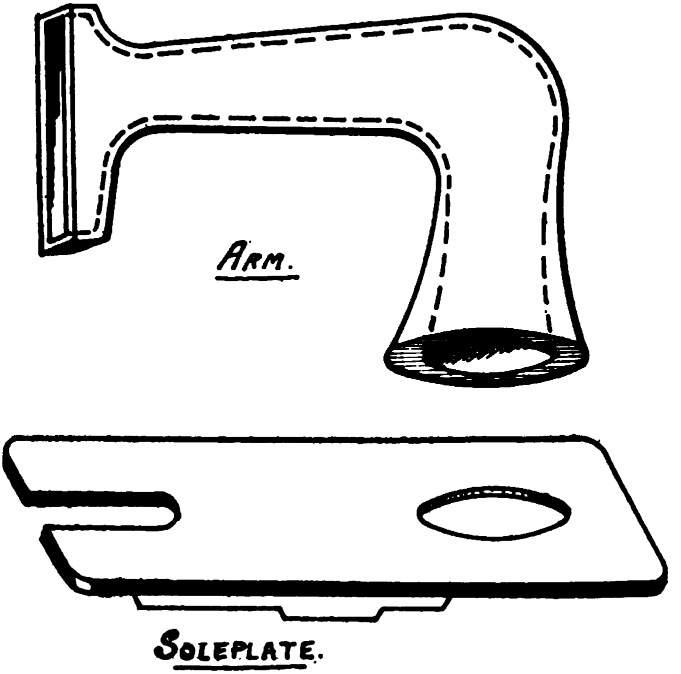


FIG. 14.—THE FRAMEWORK OF A SEWING-MACHINE.

of steel, and so we find great stores of long steel bars, rods, and sheets. These, along with the pig-iron, contain all the material for the making of a sewing-machine, with the exception of a few small pieces of brass used in the machine.

MAKING SEWING-MACHINES

Even a very casual glance at a sewing-machine informs us that the body of the machine is composed of a solid soleplate, or *bedplate*, and an *arm* rising up from that with a bend at right angles. The end of this arm is to carry the needle apparatus, while the bedplate is to carry the shuttle arrangement beneath it.

First of all this arm and bedplate must be shaped or moulded. We all have some idea of the process of moulding or casting. In our schooldays we used to cast little leaden bullets in a very simple mould, which was shaped like a hollow ball, but was in two parts and opened on a hinge, the two halves having handles, giving the whole affair something of the appearance of the household nut-crackers. When casting a leaden bullet we closed the mould and poured the molten lead through a small hole in the top of the empty mould. After giving the lead time to cool, we opened the mould and took out a nice round bullet, showing only a rough line along the join of the mould.

The bedplates and arms of the sewing-machines are cast in the same manner, but we shall pay particular attention to the moulding of the arms, as these are hollow, and therefore more difficult to cast; indeed, they were cast formerly in two separate pieces and then joined together.

In the case of the schoolboy casting a lead bullet, he merely fills the whole mould with molten metal. It is clear that if we pour molten metal into any shaped vessel, the metal, being in a liquid condition, will fill the vessel just as water would, and so when the metal cools down we shall have a solid mass. How, then, can we cast a hollow arm for the machine?

In the first place, it is obvious that, while an iron mould was good enough to hold the molten lead for our amateur bullets, we must have something better for molten iron, which is at a much higher temperature. Lead melts at 630 degrees Fahrenheit, while pig-iron does not melt until the temperature is increased to 2,000 degrees on the same scale. Hence the iron-moulder makes his moulds in sand. The usual plan is to cut out the necessary shape in wood; then, making up a box of sand, he presses the wooden pattern into it and leaves an impression of it in the sand, into which he pours the molten iron.

In Singer's moulding-shop we find the desired patterns are in the form of very massive iron boxes, into which the moulder throws the sand. He has two moulding-boxes, representing the two hinged sides of the schoolboy's bullet-mould, only, in the present case, the sides are not hinged together. Having filled one moulding-box with sand, the moulder places it in a powerful hydraulic press, which compresses the sand into the shape of one half of the hollow arm. The moulding-boxes are heated by gas. When the second half-mould is ready, the two are placed face to face, but the result of filling this sand-mould with molten iron would be to produce a solid arm, and that is not what is wanted. A third mould is therefore made, and this is a solid mould of sand representing the hollow space required within the arm. When the sand for this mould has been compressed in a pattern-box by the hydraulic press, and fired at the same time, the sand becomes so compact that the moulder can lift it out of the box and place it between the two half-moulds prepared previously. We now have in the complete mould a space between the centre part, or *core*, and the outer moulds, and this space exactly represents the walls of the iron arm required.

When the moulders have prepared a number of such moulds, one of the men fetches the molten iron from the furnace. Although the moulding-shop covers a great deal of ground, the iron is all prepared at one place, from which it is wheeled in large ladles to the different groups of moulders. From the furnace we see the white-hot liquid metal pouring forth like water, while one man after another places his huge ladle under the outlet. Things are so arranged that the flow of molten metal does not require to be interrupted, but is allowed to flow on continuously. As soon as the first trolley-ladle is filled, its owner pulls it out of the way to let the next man place his in position. During the momentary change the man who is in charge of the outlet of the furnace puts a small ladle in position, and this he empties into the following trolley-ladle whenever it is in proper position. Formerly it was necessary to close the furnace outlet with a ball of clay at each separate drawing, and this was not only inconvenient, but was attended with some little risk. The present arrangements are so perfect that the supply and demand practically balance each other, so that it is only in the event of any special delay in the return of the men with their ladles that the continuous flow of metal has to be stopped. The large ladles are lined with an inside jacket of clay, and it is surprising how long the metal remains molten. Even when the man returns with his empty ladle, after having filled the prepared moulds, his ladle is still red-hot. Quite a regiment of men are on the move between the furnace and the different parts of the great moulding-shop, wheeling these large ladles. A great transformation takes place in this department; the molten pig-iron is converted into machine arms, bed-plates, stands, wheels, and other parts. These are collected by electric trains passing through all parts of the moulding-shops.

The castings are carried on this electric railway to the *rumbling department*, the noise of which is quite inadequately described by such a mild word as *rumbling*. It is hopeless to carry on any conversation here, but one can see exactly what the noisy process is. Large revolving drums are packed with these castings, and besides these there is a large number of small scraps of iron, which fall through among the castings when the drums revolve, knocking off all the dirt and grit, which is withdrawn by an air-pipe at the end of each drum. We see one drum being opened, and it is full of the open-work castings which form the sides of the stands upon which the machines rest. A large trolley is filled with the castings, and wheeled over to the *japanning* department, where they get a bath in very black stuff. We see a big strong fellow, with his arms bare to the armpits, lift half a dozen castings at one time and dip these "over their heads" in a large tank of black paint stuff. Simply one dip down, and then they are put to drip on a sloping tray or trough. The man appears to be wearing a pair of beautiful, long, and tightly-fitting black gloves, which, however, are easily removed by washing.

The blackened stands then go to the stoving department, and after that they are handed over to the mechanics' department to have the necessary holes drilled in them. Holes have to be drilled in the feet for castors, others to fix the table-top, and so on. There is no turning of the stand one way to have one hole drilled, and then on its side to have another hole drilled. All the holes are drilled at the one time by seven separate drills. As soon as the drills have done their work they retire automatically. The man then lifts out the drilled casting, and puts another in its place, to undergo the same wholesale drilling. Needless to say, the machine itself is not completed in such a simple fashion, or it could be sold for a few shillings. It will be of interest to follow the arm and bedplate as they pass through the mechanics' shops.

We find the arms and the bedplates entering the first great machine-shop, the arms passing down the one side and the bedplates down the other, to meet at the end of the shop, ready to be joined together. Before reaching this shop, the arms have been trimmed along the line representing the join of the half-moulds. The next process is to cut the base perfectly flat and square, and to do the same to the top and bottom of that part which is to carry the needle apparatus. These operations are not done by hand; the arm is put into a machine, which cuts all these three parts at the one time.

The arm is then passed on to the next machine, which is to drill the holes in it. There is some variety of work in this, for there are no less than twenty holes, not only of different sizes, but entering from different positions. It will take a man, with an ordinary drilling-machine, some considerable time to drill out twenty holes, having not only to change his drill for each size of hole, but having to change the position of the arm being drilled also. The drilling-machine in the present case is no ordinary one; all that it demands is that the man will place the arm in the machine, turn two screws to keep it in position, and then switch on the driving power. Immediately we see twenty different drills come forward, some from the left side, some from the right side, some from the back, some from the top downwards, and others from the bottom working upwards. Whenever these twenty drills have completed their individual tasks, they all retire automatically, and the man lifts out this arm, handing the machine another armpiece to drill in similar fashion. Although this drilling is done in such wholesale fashion, there is no rough-and-ready work; every hole is exact and true.

This degree of exactness to which the different machine-tools have to work is well illustrated by some of the machines working upon the bedplates in the same workshop. Here we see a machine-tool at work, finishing off the groove, or *race*, on which the shuttle is to run. This race has been cut very smooth by the last machine, leaving a certain space for the shuttle, but this second machine has to dress it up to a greater degree of exactness. It is

By permission of *The United States Metallic Packing Co., Ltd., Bradford*

A PORTABLE DRILL

The modern workman can drill holes in massive plates of iron by mechanical drills. The workman in the above illustration is using a portable drill upon the boiler of a locomotive. He merely controls the drill, which is driven by an electric motor.

to leave the space true not only to within one sixty-fourth part of an inch, but to the one ten-thousandth part of an inch.

The sewing-machines of one type are all exact duplicates of one another, and yet it is necessary to give them some individuality, and so a registered number is stamped on each machine. The way in which a mechanic imprints a number upon a piece of metal is to take a little chisel on the end of which is the cutting type, and with a sharp blow on the other end he impresses the figure or letter of this particular chisel on to the surface of the metal. This process has to be repeated for each letter or figure to be printed. In the sewing-machine factory we find an automatic machine undertaking the numbering on its own account. The man places one of the bedplates in position in this machine, whereupon seven little hammers give seven different cutters a separate blow, the one following the other in very rapid succession. While the man withdraws the bedplate to insert the next one, the machine brings forward the next number, increasing the total number by one for each bedplate.

By the time the bedplate and the arm have reached the end of this great workshop, the two parts are ready to be united together. When this has been done, the machine receives its fine black coat, for it would not do to delay that till its bright steel parts are fitted in. There is no painting on of the black coat; the process is on the same simple plan as the japanning of the stands, but as the machine is to be seen more closely than the stand, the former will require to be more highly finished than the latter was. Hence we find a good deal of time and labour being spent over the black coat of the machine.

Before being dipped in the black stuff we find the machines getting a hot acid bath to produce a perfectly clean surface. As they cannot be put by hand into this bath, a crane lifts a great truck-load, and lowers the whole lot into one of the hot tanks; then, swinging its long arm round, it lifts another similar tray from a neighbouring hot bath, coming back shortly to remove the other lot. Each machine is then dipped by hand into a black enamel bath, and after dripping, these are wheeled away to a large stove, and baked for several hours. When the large trolley-loads of these shining black machines leave the stove, each machine is handed over to a girl, who seriously endeavours to remove all the beautiful shine with the aid of pumice-stone. Of course, she is not doing this for amusement, but in order to remove all roughness from the surface, as the machine is to have a second and a third black bath.

Even after the third bath and stoving the surface is rubbed down till it is quite dull. In this condition it is handed over to the young ladies who ornament the bedplate and arm with gilt designs. Perhaps someone pictures an expert deftly printing the freehand scrolls in gilt, or it may be that someone imagines a stencil plate being used. Either of these processes would take some time, and probably even with a stencil at least ten minutes would be required for each machine. In reality, however, what happens is this: The girl places the plain dull black machine in front of her, and lifting a transfer paper, having a damp gummed surface, she presses it on to the surface of the machine. She has a number of different transfers, and she places these quickly one after another on its proper place; then, lifting off the papers, she leaves the beautiful gilt design fixed to the surface of the machine. It is really a process of gumming on a very thin gold leaf, and so well does the gilt adhere that the girl can rub it with her hand without injuring it. A very few moments, and the whole machine is daintily ornamented; but it is still a dull funereal black, and in this condition it is stoved to fix the gilt design.

The machine has a gayer appearance as it leaves the varnishing department, and surely now it is complete. But no, we find another group of girls still ill-using the highly finished machines after they have come through a stoving process for the fifth time. These girls are rubbing the surface of the machine with that soft brown *rotten-stone* which is often used for polishing brass and other metals. The final touches are given with the palm of the girl's hand. We now see the finished article so far as the body of the machine is concerned; but before it can sew, it requires a great many pieces of machinery fitted into it.

We take a walk through the forge, where we find all sorts and shapes of steam hammers at work. One hammer, by a single stroke, forms the bent crank for converting the up-and-down motion of the machinist's feet into a rotary motion; and so on.

In another great department we find all sorts of machines punching out other parts of the sewing-machines. These parts are simply punched out of various widths of flat bars of steel. One machine will punch out the necessary shape, while a second machine will fold this piece over at right angles or into any shape required.

Many a youth derives great pleasure in working with tools, and if the amateur mechanic is the possessor of a small foot-lathe, he can produce some interesting results. One of the things which appears most remarkable to his friends is the beautiful threaded screw which he can produce. With a little practice he can cut a perfectly regular thread, using a special cutting tool on the surface of a piece of brass rod, which he keeps revolving in his lathe. If the screw is to have a fine thread he will probably use a cutting die, made of hard metal, with which he can cut the thread more easily. Either process takes a good deal of time, even in the hands of an expert; but what about the millions of screws required in the great sewing-machine factory? Here we find automatic machines doing the whole work.

The first machine cuts off a short length of rod, which immediately receives a violent blow on one end, causing the head of the screw to take shape. When these little-headed pieces leave this machine, they are handed over to another machine which cuts the groove or saw-draft on the head, so that it can be turned by a screw-driver. They pass, after this, to a screwing-machine, which forms a fine thread on each piece. All these machines feed the screws into position automatically, causing a whole regiment of screws to line up in single file in a slotted passage and enter in turn, one at a time, into the cutting part of the machine. These screws, when completed, are sent along with the other machine parts to the fitting-shop, where they are all fitted into the prepared machine bodies.

We have not followed the making of the little wheels, which are to be fitted on to the end of the arms, to receive the drive from the wheel in the stand. This little fly-wheel also provides the sewer with a convenient means of turning her machine to bring the needle into proper position for threading. Some factory girls have an idea that these little wheels possess some other function, for I recollect on one occasion hearing a dispute between a forewoman and a mechanic in a factory. She had sent for the mechanic to repair some fault of which the sewer complained. "The machine wouldn't go rightly," and yet the mechanic could find nothing wrong with the going parts. Just when I came upon the scene, the forewoman was suggesting to the mechanic that some oil on the rim of this little fly-wheel might help matters.

The suggestion was, of course, a ridiculous one, and I knew the mechanic would find it difficult to restrain a laugh, so I hastened to ask the forewoman in all seriousness if she had found this oiling of the rim to do good on any other occasion, and when she said it had done so, I instructed the mechanic to oil the rim of the wheel, pretending it was quite a reasonable thing to do. On asking him later if the cure was effective, he informed me that, strange to say, the girl had found no further trouble with her machine. I was not so surprised, for as I have often observed in connection with weaving machinery, there is a peculiar psychological condition occurring at times and materially interfering with the work of a willing employee. This, however, is more likely to occur with power-loom weavers than in connection with sewing-machines. Even in connection with the former it is somewhat rare, but it is none the less real.

We need hardly follow this little fly-wheel through all the processes of manufacture, but a rough sketch of part of its career may be of interest. From its formation it is quite clear that it has been cast in a mould, but the rim is beautifully rounded and wonderfully smooth. This has been accomplished by a machine having three cutters, which act upon the rim while the wheel is being revolved upon its axis. One cutter works on the outside of the rim, while the other two cut on the inside, one cutter on either side. These two cutters have not so much to do as the one which has to travel right across the width of the rounded rim, and so we notice that the two side cutters have ceased working and retire, leaving the other cutter to finish its task.

We need not trouble about the japanning and drilling of the wheel, but we find a very interesting motion in the machine which gives the final smoothing to the rim of the wheel. If a man were to be set this task he would hold the rim of the wheel against a revolving buffing-wheel. The wheel being polished, would be free to revolve on its axis, and would require to rock slowly from one edge of the rim to the other in order to insure an equal treatment of the whole rim. It is this rocking that would worry the workman, for it would be very difficult to rock the wheel perfectly steadily, and any irregularity would show on the surface of the rim. The buffing-machine in the present case takes the full responsibility on its own shoulders. The man merely places one machine wheel on each rocking arm of the machine, and these arms give an absolutely steady motion, producing a perfectly polished surface. It only remains to place the wheels in an electro-plating bath, whereupon a thin coat of bright nickel is deposited upon the surface by those invisible atoms which wander through the liquid impelled by electric force.

It must have occurred to some readers that the making of a sewing-machine is very much a case of the workmen merely seeing that the automatic machines do their work properly. But now we come to a department in which manual labour is required, and this is known as the *Assembling-Room.* This is quite a graphic description of the department, for here all the different parts, manufactured in widely separate departments, are assembled together for the purpose of being fitted into the body of the sewing-machine. One part after another is fitted into the ever-growing machine as it passes from one group of men to another.

When the machines are quite complete, they are placed on long benches, under which a driving shaft is running at a high speed. Belts are coupled from wheels on this shaft to the small driving wheels upon the sewing-machines. It is interesting to watch the young men putting these belts on to the driving wheels. It is necessary to place these belts on each machine as it is put in position. The inexperienced man would stoop down on each occasion and place the belt on the driving wheels of the shaft; needless to say, he would go home with an aching back. But the mechanic here adopts a more comfortable plan; one touch with his practised foot and he has placed the belt upon the revolving wheel. Every sewing-machine is driven at a high rate of speed for some time upon one of these *running-tables*, in order to ease the bearings, and thus dispel any stiffness in the going parts of the machine.

That every part fits well is guaranteed by the careful tests made of all the diameters of the shafts after they have been made and turned to the required sizes. Sometimes when one is measuring a manufactured article, one may say it will do very well, as it is not more than a sixty-fourth part of an inch of the exact measurement asked. Every sewing-machine shaft, however, which is one two-thousandth part of an inch too large or too small is returned as imperfect.

After the machines leave the *running-tables* they are carefully examined by experienced mechanics, and unless they are perfect they are returned to the fitters with a note of the defect, such as "shaft stiff," "wheel off the truth," "rock on end of shaft," and so on. The fault may be a very small one, which the examiner could put right in a moment, but in order to keep the fitters up to the mark, he must not repair it himself; the machine must be returned to those who were responsible for the defective fitting of that particular part.

When the machines have passed this very critical examination, they are placed on benches and driven at their ordinary speed, so that sewers may adjust the tensions to the class of work for which the machines are intended. After the machine is stitching satisfactorily, the sewer works a small sample and leaves it to be sent out along with the machine.

During these trials of the stitching capabilities of the sewing-machine it has been on a bench fitted with a power-driven shaft. The machines may be for factories in which they are to be similarly fitted up, or they may be for private houses, in which case each machine will want a separate table or stand. We have seen how the metal stands were cast and drilled, but it remains to be seen how the table-tops are made. There cannot be much in this—simply an oblong piece of wood! But the manufacturer knows better than to run any risk of the table warping and twisting, so he adopts a more scientific plan. He makes the table-top of five sheets of thin wood, or *veneer*. These are placed one on top of the other, but so arranged that the graining of the one veneer is lying in an opposite direction from that of its neighbour. These sheets of wood are passed through a sort of mangle, the rollers of which are continually covered with melted glue. Five sheets are then placed together and compressed in a hydraulic press. When perfectly dry these five-fold blocks are treated by specially arranged circular saws, planes, and other machines, until the table-top is ready for polishing.

One expects to see the floors of these immense cabinet workshops covered with sawdust, but there is no sign of sawdust anywhere. The fact is that the sawdust never gets a chance of even falling down to the floor; it is sucked up by large funnelled pipes placed over the cutting tools, and is driven by air along those pipes to a considerable distance till it reaches the boiler-shed. Here all the sawdust-pipes unite, and feed the furnaces of a large boiler required for heating the workshops. There is a continual downpour of sawdust into the furnaces all day long. The furnaces of a neighbouring boiler are fed by the chunks of wood which are too large to be sucked up by the air-propellers which produce the draught in the sawdust-pipes. These fragments of wood are conveyed from the workshops to the furnace by means of a light overhead railway. Everything is done to economize labour, and it is evident that the enthusiasm of the original Isaac Singer is still maintained.

CHAPTER XI

THE AUTOMATIC NEEDLE-MAKERS

NEEDLES must have been very awkward things to make before machines were taught to do this work. There is a fine groove on two sides of the needle, and a very neat little eye in this groove. In the sewing-machine needle the eye is near the point, while the other end of the needle is much thicker, and has a flat slab cut upon it, so that it will fit into the needle-holder and keep the eye in its proper position.

This needle-making department is one of the most interesting in the great Singer factory; the automatic needle-makers seem *almost* human. No one will make the mistake of thinking that needles are cast in moulds. We have seen enough concerning rough edges on the iron castings to put moulding out of court for this purpose, even had it been a convenient method otherwise.

Needles were made entirely by hand for a long time. Men cut the steel wire into pieces equal to the length of two needles, the two ends of which were ground down to form the points. The centre was flattened, and had two little oval holes pierced in it, these being placed close together, so that when the wire was cut between these each piece formed a needle in a somewhat rough state. A number of the needles were then placed in a vice while a workman filed the heads till they were nice and round. After this the eyes had to be smoothed, and the needles polished and tempered. All this meant an immense amount of hand work, and one can imagine how difficult it would be to work with such small things as needles; indeed, on this account it was a common practice to employ children for piercing the eyes of the needles. In the modern process of manufacture the needles are not handled at all; they are made entirely by very ingenious automatic machines.

We find great reels of steel wire, from which the sewing-machine needles are to be made. This wire is fed into a machine which straightens it and cuts off one inch at a time, while a little metal arm with two fingers catches the little bits and places them in a miniature rolling-mill. The one-inch wire is rolled out to about one and a half inches, leaving at one end a small shank of the original thickness of the wire. These pieces are then pulled out of the rolling-mill by the little fingers, which deposit them in the collecting-box.

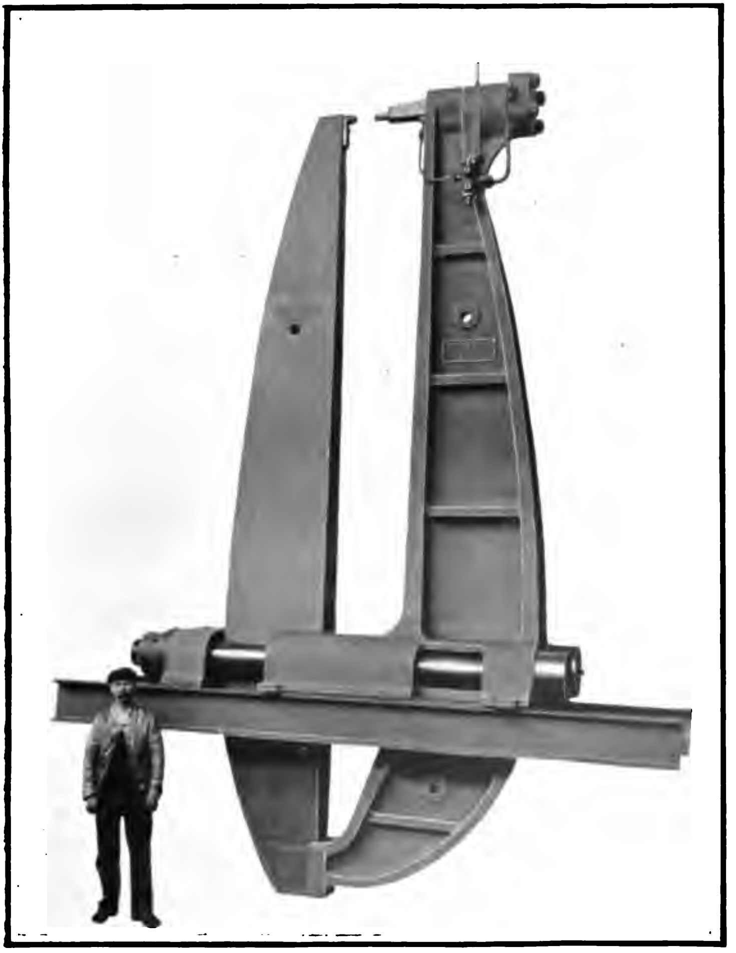
The next process is to cut a groove for the thread on both sides of the needle, so the little rolled pieces are handed over in bulk to the grooving-machine. This machine feeds the pieces forward, one at a time, towards a little arm, which closes its two fingers upon the shank-end of the needle and lifts it over to a pair of cutters. While these cutters are making the groove, the little arm has returned to fetch a second needle, and while it is doing so a second pair of fingers takes hold of the first piece and lifts it out of the cutters, placing it upon a sloping tray, and releasing its fingers so that the needle rolls down into a collecting-box; this second arm returns to lift away the next needle from the cutters. It is really quite eerie to stand and watch this machine working away by itself, each arm attending to its work as though the machine actually knew what it was doing.

These partly-formed needles are now handed over to the slabbing-machine, in which there are no less than eight grindstones, against each of which the shank of the needle is pressed in turn till the flat slab is completed. The machine takes entire charge of the needle in its passage from one grinding-stone to another. After this the needles are entrusted to the machine which puts the points on them, and the needles are kept revolving during this grinding process.

It still remains to pierce the little eye in the groove near the point, and this process is the most interesting of all, for the machine has certainly a very delicate and difficult task to perform. The needles are fed along by a spiral screw, so that they lie side by side at a little distance from each other. The first difficulty is that the machine must not merely pierce a hole in the needle, but this eye must be through from the one groove to the other. The machine is equal to this task, for on its way to the piercing apparatus the needle is caught by a pair of fingers, which turn it round, so that it lies with the grooves in their proper position. Then it will not do to pierce the hole to one side or other, and yet the width of the needle is so very small that it would seem almost hopeless to strike the very centre. A second pair of fingers place the needle absolutely straight, so that the hole is pierced exactly where it is required. It is worth while taking a look at a sewing-machine needle through a magnifying glass. It is remarkable how regular and well-shaped the eye and the grooves are made.

Not only are the needles nicely polished after this, but it is necessary that the eyes be perfectly smooth, or the sewing-thread will be cut in its passage through the eye. With this in view, the needles are all threaded by girls, and they can do this so quickly, sometimes a dozen needles at one time, that there seems no need to trouble about a machine for threading needles. I have seen such a machine in use on the Continent for threading the two-pointed needles with the eye in the centre for use in the hand embroidering-machines. However, one can hardly wish for anything better than those human expert needle-threaders employed in the sewing-machine factory. When the needles have been threaded, some emery powder is rubbed on to the threads, and drawn to and fro through the eyes. A machine is now used for this purpose, as it is necessary to give the needles a very regular rocking motion, while the emery thread files away all rough edges in the eyes.

The manufactured needle is now complete, but no less than two hundred men are employed all the year doing nothing but seeing that the needles are straight. Each man has a little sloping anvil on which he rolls each



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A GIGANTIC RIVETTER

This great hydraulic tool is used for rivetting large boilers. A crane suspends the boiler so that it fits over the left-hand pillar like a finger-stall. The rivet-head, which is inside the boiler, rests against the projection at the top of this pillar, while the little piston at the top of the right-hand pillar takes the place of the human rivetter, forming a head on the outside and thus binding the boiler-plates together.

needle, tapping it gently with a very small hammer until it is perfectly straight.

It only remains to put the needles up in paper packets, and even here machines are now coming into use. One machine selects three needles, and fixes them through a piece of paraffined paper, which it tears off a large reel. The machine then lays this on a piece of black paper, which it folds up into the form of an envelope or packet, and delivers ready for sale.

In this giant factory every precaution is taken for the safety of the employees. When the great crowd of workers are leaving work for the day, it is a case of "ladies first," so that the girls are clear of the buildings five minutes before the great stream of men leave. This is a wise precaution, as the majority of the men make a rush for Singer Station to secure seats in the first of the special trains which carry them in thousands to Glasgow.

Another point of interest is the storing of the large quantities of inflammable oils required for lubricating the hosts of machines in each department. The oil is stored in underground tanks in a large one-story building, which has no windows in its walls. When any department requires oil, a telephone message is sent down to this oil-store, where certain connections are made that enable the department to pump up the quantity required, and nothing more.

We have seen that sewing-machines and their needles are made by machinery, and it is interesting to note that this great factory also makes the machines which make these articles, and these machine-making machines are also made by other machines. This statement recalls the nursery rhyme, "This is the house that Jack built," for we might say: "These are the machines that make the machines that make the sewing-machines that make the seams that make the clothes"; but we should not add that the clothes make the man.

Throughout the whole factory, machines are made to do the work wherever it is possible. Even the nailing of the thousands of packing-cases required daily is done by machinery. The sides and ends of the boxes are merely placed together, and one stroke of a large machine nails each side in turn, the bottoms being fixed in a similar wholesale fashion.

All sorts of sewing-machines are made in the same automatic fashion as has been described in the preceding chapter. Some machines make button-holes, while other machines sew on buttons. Some machines have no less than six needles working simultaneously side by side. Some machines make hems, while others make *tucks* and *gofferings*, and so on.

CHAPTER XII

THE ROMANCE OF THREAD-MAKING

THE thread trade of Paisley came very prominently before the public some years ago, owing to the unprecedented advance in the market value of Coats's shares when that large business concern was converted into a public company. Ten-pound shares rose as high as one hundred and ten pounds, and all along this business has proved a great financial success, ultimately amalgamating with all the large thread-making concerns, and forming one large combination.

It is not the commercial aspect with which we are interested here, but the processes by which sewing-threads are made, and the means by which the present position has come about.

It is always of interest to trace how any particular industry became settled in a particular district, and how often we find that it was the action of one individual that forms the real basis.

The spinning of yarns for weaving purposes was practised throughout Great Britain long before any attempt was made to manufacture sewing-thread. The woollen and linen yarn spun for the loom was of no use for sewing purposes, its strength being quite insufficient.

Among those living around Paisley during the closing years of the seventeenth and the opening years of the eighteenth century was a country gentleman—John Shaw—who owned a small estate called *Bargarran*. One of Shaw's daughters—Christian—who was very delicate, as will be seen from the accompanying footnote, was an excellent spinster.* Having married a clergyman of the name of Miller, and being left a widow after a few years of wedded life, she returned to Bargarran. Here she set to work earnestly, producing very fine linen yarn for some of the Paisley weavers, who were making fine lawn cloths.

It occurred to this young widow to try and make sewing-thread such as the Dutch were supplying at that time to Great Britain. The sewing-thread was made by twisting or twining together several strands of linen yarn. Mrs. Miller was successful in getting a twisting-machine brought over from Holland by a friend. This machine operated a dozen bobbins at one time, twisting the yarn into thread. The machine was, of course, merely driven by hand. The results were excellent, and the young widow was soon producing a sewing-thread quite equal to that imported from Holland.

Bargarran estate lay near the Erskine Policies of Lord

* Christian Shaw, who was born in 1685, suffered from an ailment which the doctors of those days could not understand, and, as the age of superstition still reigned, they jumped to the conclusion that the girl was bewitched. Three men and four women were believed to be guilty of bewitching her, and after being "found guilty" at a trial in Paisley, they were put to death in 1697.

Blantyre, and Lady Blantyre became interested in the fine sewing-thread which her neighbour was able to produce. On one occasion, when Lady Blantyre went to the town of Bath (England), still a famous health-resort, she took with her some of Mrs. Miller's sewing-thread. Some of the lace-makers in Bath were so pleased with the thread when it was shown to them that an immediate demand sprang up for this Bargarran linen thread. The demand became so great that all the daughters of the house and many young women in the neighbourhood were set to work at other twisting-machines.

Mrs. Miller went to reside in the small town of Johnstone, which lay between her home and Paisley. There she carried on the manufacture of linen sewing-threads. It is interesting to note that at the present time the chief industry in Johnstone is the manufacture of linen sewing-thread, there being large modern factories at work.

It was only natural that others took up this profitable occupation, and so we find many twisting-machines at work in the neighbouring town of Paisley. Before the close of the eighteenth century there were over one hundred such machines at work in this old weaving town.

In the meantime Lancashire was busy manufacturing cotton-weaving yarns by means of the inventions described in an earlier chapter. The Paisley "buddies" (bodies), as they are called, procured some of this fine cotton yarn from the South, and they found that when twisted on the thread-making machines it made a very fair imitation of the linen sewing-thread, although it could not be compared with it for strength. The tailor still sews on buttons with linen thread. It was found, however, that the cotton sewing-thread could be made much more regular than the linen thread, and it cost very much less, which was a great consideration. When it was found that a six-ply cotton sewing-thread was strong enough for ordinary purposes, its use became very general.

It so happened that about the beginning of the nineteenth century the wearing of Paisley shawls went out of fashion. Up till that time no lady's trousseau was complete without a Paisley shawl, with an elaborate design woven by the Jacquard machine. The shawl trade had made Paisley a very prosperous town, so that the decline of this trade entailed a great deal of hardship. This fact alone would induce many people to try their hands at twisting sewing-cottons. But in addition to this, as we shall see from the succeeding chapter, the sewing-machine made its appearance, so that there was a new demand for sewing-cottons.

At this time sewing-cottons were sold in hanks, just as knitting-wools are sold to-day, and no doubt the young folk of that time would be called upon to stand patiently with outstretched hands to hold the hank while the mother or sister wound it into a ball.

There was one Paisley heddle, or heald, maker—James Clark—who supplied ladies with these hanks of cotton thread, and there seems little doubt that he became a favourite with the ladies, for he offered to save them the trouble of winding the hank at home. He got a local wood-turner to supply him with small wooden spools or bobbins, and if a lady cared to wait, he would sit down at a weaver's winding-wheel, and wind the hank of cotton on to the spool. As the spool cost him one halfpenny, he charged the lady the cost of this, but promised to refund the money if the spool was returned when empty. It will be observed that the labour of winding the spool was not charged for. I have been told by a grandson—also James Clark by name—that his grandfather used to walk round to the wood-turner's and fill his own pockets with the wooden spools, which he used in the manner already described.

The increasing demand led to the factory system of twisting and winding sewing-cottons, and from this small beginning there grew up the gigantic business of J. and J. Clark, in Paisley.

About the same time a Paisley weaver—James Coats—who had become a cloth manufacturer on his own account, and had met with financial success, turned his attention to the making of sewing-cottons. No doubt he foresaw that this thread-making business was more likely to be a steady one than the fickle cloth trade, which changed with changing fashions. James Coats, whose brother Peter joined him as a partner, soon made a great name for his sewing-cottons, the firm being known as J. and P. Coats. Coats's thread could be depended upon for quality, and the purchaser could be sure that whatever length was marked upon the bobbin was really there. This was not the case with some unscrupulous makers, whose conscience allowed them to mark a bobbin three hundred yards while it contained only the half of that quantity.

The first steam-engine which the Coats put into their mill was equal to twelve horse-power, but their modern mills each require from fifteen hundred to two thousand horse-power, while the combined horse-power of the Coats and Clark mills in Paisley equals thirty thousand horse-power. The furnaces for supplying the necessary heat burn over one hundred thousand tons of coal each year, which means about four hundred tons every day, or the output of several coal-mines.

When one sees the stream of workpeople pouring forth from these factories at closing time, one is not surprised to learn that there are over ten thousand employees, the majority of whom are girls. But when one sees the inside of one of these great factories, it is not the number of the workers which impresses one; it is rather the sparseness of workers compared to the size and number of the machines. On one flat we find a great number of machines apparently working away on their own account with a comparatively small number of workers keeping watch over them. In some departments, however, we find a great many workers together, as we shall see later.

It is natural that the directors do not throw their mills open to the general visitor, or they would require a special staff to deal with the applicants, and also, from a business point of view, it would be bad policy to let possible sharks within their gates. I am pleased, however, to be able, through the courtesy of the firm, to take you, in imagination, through one of these great factories.

We wish to see, first of all, the making of the little wooden bobbins upon which the thread is to be wound. We find immense stacks of birch-wood cut into bars a few feet in length and measuring about two inches square. When we see the vast extent of these timber stores, we are not surprised to learn that the firm use about fifteen thousand tons of wood each year. Perhaps the magnitude of this may be better understood when we consider that the bobbins produced in one year could be dealt out so that every man, woman, and child in the United States, Great Britain and Ireland, Germany, France, and Italy, might each have a bobbin.

But how are these bars of wood converted into the shapely bobbins? First of all, the square bars are fed into a turning-machine from which they emerge immediately in the form of round rods. The diameters of these rods are a little greater than the finished sizes of the flanges of the bobbins are to be. These round rods are passed through a sawing-machine, which cuts them into the required length for the bobbins.

These little solid blocks are then poured into the feeding-box of an automatic boring-machine. The machine feeds one little block forward at a time, and holds it firmly in the correct position while a revolving drill pierces it lengthwise, producing that nice round hole through the centre. These bored blocks are now examined, and any faulty ones are thrown out as waste, the chief fault being knots in the wood. Those blocks which pass the scrutiny are poured into the feeding-box of another machine which is remarkably active. Indeed, so quickly does this machine do its work that it is impossible to follow its movements with the eye. All that one can see is that the little wooden block is revolved at an enormous speed, while a cutting tool moves forward and suddenly transforms it into a bobbin, and a ribbon of wood-shaving flies into the air. Then, without seeing any actual change taking place, you suddenly find another little wooden block has replaced the finished bobbin, another transformation, and another fresh beginning. One's eyes cannot follow the ejection of the finished bobbin and the introduction of the next block, and so we know that the actual change of bobbin for block does not occupy one-tenth part of a second, or it would make some impression upon the eye.

In this turning-shop we see a great crowd of machines at work, making various shapes and sizes of bobbins, and all throwing out long shavings. These would soon accumulate upon the floor and impede the movements of those carrying the material to and from the machines. But a part of the floor is always on the move, and the shavings falling upon this are carried to the end of the building and ejected into a pit outside. Here there are large bags in position to catch the shavings, and a wooden plunger descends with considerable force, pressing great the shavings very firmly into the bag. When these bags are filled they are despatched to some local chemical works, which extract ammonia from the wood-shavings.

The finished bobbins are examined, and any faulty ones are discarded and added to those already laid aside as waste. The bobbins are then counted, but needless to say they are not counted individually. They are tumbled into a large receptacle which is fixed above a table containing large trays. These trays are divided off into little separate compartments, each of which can hold one bobbin only. There are one hundred and forty-four of these spaces, so that when the trays are filled they contain exactly twelve dozen, or one gross, of bobbins. By opening a trap-door arrangement in the bottom of the large receptacle holding the bobbins, a quantity falls out on to the trays. The man in charge sweeps these across the trays with his hands so that every compartment is quickly filled. The trays then disappear down into the table, tilt the bobbins out into a basket, and the empty trays return into position upon the table. Each time the trays dip down with a full load they register the quantity upon a paper ribbon, punching one hole to represent each gross of bobbins.

We have seen in an earlier chapter how the spinning of weaving yarns came about, and in the present chapter we have seen how these yarns spun in Lancashire came to be twisted together in Paisley, so that they formed a thread capable of being used for sewing with. Originally these great thread-mills devoted all their attention to the twisting and winding processes, depending partly upon Lancashire for the single spun yarn. But now we find the Paisley factories also spinning the single yarn on their own account.

The cotton fibre is delivered in bales, and in this condition the individual fibres are lying higgledy-piggledy in every possible direction. The first process is to arrange them into some form in which the material may be handled conveniently. This is done by the *scutching*-machines, which tease out the cotton material and form it into a sort of web, not unlike a long sheet of wadding, but without the flimsy protecting cover. These webs of cotton, about one yard wide, are transferred to the *carding*-room. Here the cotton passes through a further teasing-out process, and undergoes a sort of combing which helps to lay the fibres parallel to one another. During this carding process the web has been drawn out in length very considerably, and as it leaves the machine it is run together into a sort of loose rope called a *sliver*. These slivers are run on to large reels and then taken to the *lapping*-machines, in which a number of these reels, or laps, are run together into one narrow web, or *ribbon*, about one foot in width. By this time the fibres are much more evenly arranged, but a further mixing is required to prevent a lot of long fibres turning up at one place, or a lot of short fibres at another place, which would cause unevenness.

In order to equalize the distribution of fibres as much as possible, a number of these *ribbons* are run together and thoroughly combed, so that the fibres are laid as parallel as it is possible. The cotton still remains in a ribbon form, and passes through a *drawing*-machine, which pulls the ribbon out in length very considerably, and at the same time some knife-edges clear away any loose short fibres.

The cotton is still in the form of loose cord, or sliver, but now the fibres are lying parallel to one another, owing to all the combing processes they have passed through. There has been also a good deal of drawing out, so that what appeared in the earlier state as a loose rope is now about the size of a fairly fine cord, but with practically no twist upon it.

During the next process it is passed through *slubbing-machines*, and these give it a slight twist as it is wound on to large wooden tubes. It then passes through two other flats of the mill, where it is further drawn out, until ready to enter the spinning department. At this stage it is in the condition of a fairly fine yarn, with very little twist upon it. The fibres are easily drawn apart, whereas they must have them firmly interlocked before the yarn can be put to any useful purpose.

In the spinning department this soft yarn or rove is spun into yarn of the same nature as is used for weft in weaving. There are two methods of spinning—*mule-spinning* and *ring-spinning*. We shall pay attention to the former, as it is of interest in connection with what we read in Chapter II. about Crompton.

While we stand and watch the mule-machine at work, we see in its motions the principle of the old distaff and spindle, and the later hand spinning-wheel. In both these primitive processes the spinster drew out a certain length of the roving, and then caused the spindle to revolve so that a twist was given to this drawn-out rove. This is imitated by the mule-machine, for as the rove is led towards the spindle the yarn passes through between two pairs of rollers, one pair revolving faster than the other pair, so that the faster rollers feed the yarn forward quicker than the other rollers are passing it to them, and in this way the rove is drawn out to the length required. The rollers are feeding the drawn-out rove to the revolving spindles, which are mounted on a carriage so that they can travel outwards as the rove is paid out to them. It is curious to see this travelling carriage, with its quickly revolving spindles, moving out a distance of some yards and then returning automatically.

Let us watch what happens while the carriage is travelling outwards. As the yarn is attached to these fast-revolving spindles we should expect it to be wound upon the spindle at each revolution, but this does not take place. The spindles are tapered and placed at such an angle that at each revolution the yarn slips over the point of the spindle, and, instead of being wound up, receives a twist at every turn. This twisting continues until the carriage has reached the end of its journey. Just then the feed-rollers cease to pay out any more yarn, and as the carriage retraces its steps the spindles revolve slowly in the opposite direction from their previous motion, while a wire guide holds the yarn well down on the spindle, so that the length of yarn stretching between the feed-rollers and the travelling carriage is wound upon the spindle as the carriage makes its way back towards the feed-rollers. Here we see an exact imitation of the old-time spinster drawing out a certain length of rove to the required fineness, putting a twist on it by the revolving spindle, and then winding it on to the spindle.

The spinster controlled one spindle and one thread, but there are hundreds of spindles in each of these spinning-machines, and under the charge of one girl. Of course the machine is perfectly automatic, so that she has only to watch that no ends break; and so well do the machines work, one girl can look after two of them, tying in all broken ends. As I have already remarked, the outsider is greatly impressed with the preponderance of machinery to workers in these preparatory departments.

Now we have a spun yarn, but not what the householder calls *thread*. One would not like to have one's clothing sewed with this spun yarn; indeed, the sewing-machines would refuse to work with such a thread. It only remains, however, to twist a number of these spun threads together to form a sewing-thread. It is common practice to have six of these single threads twisted together to form a *six-cord cable-thread*.

We come now to what is perhaps the most interesting process of all—the winding of the cotton thread on to the little wooden bobbins. Our interest lies in the capabilities of the automaton, and we shall see how complete the machine's work is in the present case. Here we see a veritable hive of industry; the human element is much more conspicuous than in the preparatory departments. This, however, does not signify that the machines are less automatic, but rather that the machines are more compact. If we stand and watch one of these spooling-machines at work, we shall soon be able to follow its different movements.

The machine is kept supplied with empty bobbins, and each section of the machine helps itself to these as required.

Just as we arrive the bobbins, which are revolving, are almost filled. We see a small guide travelling to and fro spreading the thread evenly over the bobbin. As soon as the requisite length of thread has been wound upon the bobbin the spindle stops revolving, and a little metal finger, which has been idle up to now, moves across the bobbin carrying with it the loose thread. At the same time we notice a little knife approach the flange of the bobbin and cut a notch in it. Then a second little finger catches the thread as soon as the first finger has carried it over the notch. This second finger moves downwards, pulling the thread firmly into the notch. As soon as this is accomplished the thread is cut free from the bobbin, which is pushed automatically off its spindle, while an empty bobbin is pushed forward into position by one metal finger, whereupon another finger comes to its assistance and presses the bobbin on to the spindle. But how are we to get the thread started on this empty bobbin?

The means by which the thread is fastened to the bobbin to give it a beginning is very ingenious. When the thread was cut in order to free the filled bobbin, the free end of the thread left was caught by a clamp, which pressed it firmly against the flange of the next empty bobbin. As this presser revolves with the bobbin, the thread commences to wind round the bobbin as soon as the spindle begins to revolve. The automaton has got over the difficulty of starting the thread on the bobbin, but it will be observed that in doing so it has bound the bobbin to the revolving spindle, so that the bobbin will not be free to be pushed off. The machine, however, does

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MAKING SEAMLESS BOATS

The hydraulic press shown in the lower illustration forces or stamps a plate of steel into the form of a boat. Some of the complete seamless boats are shown in the upper illustration.

not overlook this point, for while the thread is being wound on to the bobbin we see a little arm moving very leisurely towards the flange of the bobbin. The end of this arm has a knife-edge, and with this it cuts the binding thread, retiring leisurely, but in good time, to be out of the way of the other quicker-moving fingers, which have to fasten off the thread into the notch, and arrange the thread for the next bobbin. What could be more automatic? The machine goes through all the necessary operations without any outside control except to see that it is kept supplied with thread and empty bobbins. A separate winding-machine is not required for each bobbin, but a number of spindles and sets of moving fingers all receive motion from the one source, and form a large machine with these sections working in sympathy.

All that is now wanting is to stick the little round labels on the flanges of the bobbins. I can remember going through one of the Clark's Paisley mills many years before the great amalgamation of the firms, and at that time all the labels were stuck on by girls in the same manner as the householder sticks a stamp upon a letter. Each girl placed a number of the round gum-labels in her mouth, and then, withdrawing them very rapidly, one at a time, she stuck them on the upturned ends of the bobbins in a tray. The same operation had to be repeated, in order to label the other ends of the bobbins. An improvement was made upon this plan by giving the girl a long pad with a perforated copper top, which damped the label as it was made to slide across the perforations. This, however, was still a manual performance. Our interest in the matter lies in the most modern method, which is entirely automatic.

This labelling-machine is not a large machine, and has a revolving piece not unlike the wheel of a wheelbarrow, but minus the rim. It has several brass spokes, or arms, each of which is hollow, and is connected to an air-pump. The movements of this revolving part are spasmodic. While it rests for a moment, one spoke sucks up a gum-ticket. The next forward motion brings this label against a damp pad, while the next step places it facing one end of the bobbin. We have been watching only one part of the machine. There is a second revolving arrangement with similar spokes, working in sympathy with this one, and so placed that it brings its damped label to face the first one. One wheel carries the labels for one end of the bobbins, while the other wheel carries the labels for the opposite end. One label bears the particulars of length and quality of thread, while the other bears the maker's trade-mark.

As soon as a bobbin has been placed automatically between the two revolving wheels, they close in towards each other, so that the opposing spokes with the damp labels press on the ends of the bobbin between them. When the spokes withdraw, the labelled bobbin is passed on between two parallel pads which press the tickets firmly on, just as though one kept one's fingers on for a little to insure a stamp sticking fast.

When the bobbins leave this labelling machine, they undergo a final examination. Any that are imperfect in any way are thrown to one side, and so the good name of the makers is upheld.

And so we see how hand-labour has been replaced by clever automata, and how these have brought sewing-cotton within the reach of all. Every household uses a lot of sewing-cotton, and yet the most careful housekeeper does not reckon this as an expenditure of any consequence. Little did James Clark think, as he gratuitously wound the ladies' purchases on to bobbins in the beginning of last century, that he, along with his fellow-townsman, James Coats, each working in his own small way, was laying the foundation of one of the most successful of all modern manufacturing industries.

CHAPTER XIII

THE AUTOMATIC SHOEMAKER

It is not intended that the title of this chapter should suggest the idea that there is any one individual machine which will accept the raw leather at one end and deliver the complete boots at the other end. But as we take a walk through a modern boot factory we shall be impressed with the idea that each workman is really a master, making his machine do the work for him.

Of course the old cobbler, sitting at his *last*, had to do every part of the boot himself, until it became the practice to buy the uppers ready-made from the factory. But if a hundred cobblers had agreed to work together, they would have found it economical to divide the labour, giving each man or gang of men one particular part to make, while others would have united these various parts to form the complete boot. Needless to say, this is the plan adopted in the making of boots by machinery; each machine has one definite task to perform.

The *uppers* are dealt with on the upper floor, and the *bottom stuff*, as it is called, is handled on the bottom floor, not in order to get the names to agree, but because light machinery is able to do the necessary work upon the uppers, whereas it requires heavy machinery to tackle the bottom stuff, which includes the soles and heels.

The first thing that concerns the boot manufacturer is buying the hides from which the boots are to be made. Immense quantities of these are required to feed a modern factory which makes thousands of pairs of boots every working day. Among the stock we find goatskins, calf-skins, sheepskins, and the well-known cow-hides. A large proportion of all these hides comes across the seas from China, India, South America, and South Africa. The soles of the boots we are wearing to-day were probably part of an animal which was careering over some far-distant ranch not so very long ago.

There are two factors which the bootmaker has to take into account when buying these hides, and those are quality and surface area. Until recently he had to judge the latter by his eyesight, but even with experience this was necessarily a rough-and-ready method. We all know how very irregular in shape a hide is. Even those who have not seen hides in their rough state have seen skins sent home by friends abroad, which skins, with the hair still attached, are used as rugs for the floor. Even in these we can see the irregular shape all round the hide—the fore-legs, the neck, the belly, and the hind-legs.

If the seller could only tell the manufacturer the actual surface measurement in square inches, then he would know exactly what he was getting, and he could compare one class of hides with another. But it would take an expert mathematician some time to calculate the surface area of such an irregular shape, and the manufacturer is not going to pay a fee to a Civil Engineer to survey each hide. If some ignoramus were to suggest that the manufacturer should employ a machine to do the measuring, the suggestion might appear sarcastic, and yet that is what the bootmaker really does. A machine which will add up rows of figures in pounds, shillings, and pence is a thinkable idea, but it would take a lot of guessing to arrive at the means by which a machine could survey the irregular surface of a hide. Possibly the very idea of such a machine conjures up some remarkable automaton such as the chess-player referred to in an earlier chapter, and which turned out to be a fraud. There is no room for trickery in the present case, as the machine must be an honest worker, and one that will not tire with constant calculating.

The general appearance of this measuring-machine is a long metal roller, over which a large number of smooth metal wheels are placed side by side, and at a little distance from each other. These wheels look, at first sight, as though they were resting on the large roller, but there is a very little clear space between the rims of the wheels and the surface of the roller. The space is so little that when a flat hide is passed through between the roller and the wheels the latter are raised up very slightly. The large roller is driven round on its long axis by means of an electric motor or other prime mover, so that as soon as a hide is laid between the roller and the wheels, the hide is carried right through from the front to the back of the machine, both the roller and the wheels revolving meanwhile. As long as any part of the hide is between the roller and a wheel, that wheel remains raised, and in this position it engages with the counting mechanism. Each wheel, when raised, adds to the motion of the indicator upon a large dial on the front of the machine. It is obvious that the wider the hide is the more wheels will take part in this addition, and the longer the hide is the longer time will the wheels continue to move the indicator forward. If we watch one of the wheels under which the irregular side of the hide is passing, we see that this wheel operates the counting mechanism for a moment as the fore-leg part of the hide passes under the wheel; the next moment it has ceased to count, for the body of the hide does not extend so far as this wheel. Now and again a bit of the irregular belly part will pass under this wheel; then comes the hind-leg part, and the little wheel takes a faithful record of them all. It may be mentioned that the wheels are kept in continuous motion to prevent skidding, but they only count when raised. Whenever the whole hide has passed these reckoning wheels, the actual surface area of the hide is shown upon the dial in square inches, and also in the metric system. So faithfully does this machine do its work that both the buyers and the sellers are willing to accept its calculations without any questioning.

As it is *machinery* in which we are interested at present, we shall not trouble with much detail of the department in which the cutting out of the lighter material for the uppers is carried on. Until recently this was done entirely by hand, but simple machines are being gradually introduced to replace the hand-worker, who is called a *clicker*. Each machine will, of course, require a clicker to work it, but then one machine can do a great deal more work than a man. When the work is done entirely by hand, the man places upon the hide a piece of zinc having the shape of the part to be cut out, and with a sharp knife he cuts right round the edge of the metal pattern. Considerable experience is required to know exactly what parts of the hide to use for different pieces of the uppers, and how to cut up a hide with as little waste as possible. The *clicking* machine enables the man to cut out the whole shape with one stroke of the machine. The method is not unlike that of the cook when making round or triangular scones or cakes. The cook has certain sharp-edged shapes which she presses down upon the material, and produces scones with an outline the same as the metal shape used. The clicker is provided with similar sharp-edged shapes, which he places upon the hide, and then by touching a handle he causes the machine to give a sharp and sudden pressure upon the top of the sharp-edged tool, thus cutting out the desired shape. Those shaped parts of leather are all assembled together and sent through to the making-up department.

This department, in which the uppers are put together, has very much the same appearance as any making-up department in the soft-goods trade. Here we see hundreds of those sewing-machines in whose manufacture we were interested in an earlier chapter. Most of the machines here are of a heavy make, as they have to sew through leather. Needless to say, they are all driven by

power. It would be tiresome to follow every operation in this department, as the detail is far greater than one would imagine. We pass over the fitting together, in which sticky substances play a part, and see these when in position handed over to the sewing-machines. We cannot fail to be interested, however, in the machines which are sewing buttons on ladies' boots.

The girl who is controlling this machine does not concern herself about the buttons; the machine itself takes entire charge of these, holding a quantity of them in readiness in a box, or "kettle," on the top of the machine. In this kettle a revolving brush arrangement keeps hustling the buttons hither and thither. One by one they fall into a race-way, along which they move in single file. The machine has the sense to turn the buttons with their metal shanks all in the one direction, so that it can place them upon the boots in the proper position for stitching. The manner of accomplishing this is really very simple. The race-way is not wide enough to allow a button to go in head first or tail first, so that it is only when the button, in its hustling, approaches the entrance to the race-way sideways that it has any chance of entering. Even then it must have its tail, or rather its shank, to the right-hand side, where there is a groove into which the shank can pass, and in this position the button can slide down the race-way, the groove extending the whole way, and keeping the buttons in position. The race-way is always filled with a regiment of buttons, and when the operator releases the machine it places a button upon the boot, and the needle stepping quickly from one

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side of the shank to the other, sews the button on, never striking the button or the shank in its rapid jumps. All the buttons required on the boot are securely sewed on in far less time than the average schoolgirl could have prepared her needle and thread for sewing on a single button.

Another lot of machines are busy making the button-holes. These machines each possess a little knife, but the machine is so expert with its knife and needle that one scarcely notices what is really taking place, except that a solid boot-flap enters the machine and comes out with a neat row of sewed button-holes.

Lacing boots are handled also by similar automatic machines. The old cobbler had to punch the holes in the leather, place the hooks in these in their proper positions, and then clinch the hooks at the back. The automaton does all this without any assistance, and never puts a hook in with its head turned the wrong way. It is amusing to watch it fishing for the hooks. These are placed higgledy-piggledy fashion in the "kettle," in which a metal star keeps revolving in an upright position. As its arms dip down and pass through the sea of hooks it catches those which happen to be in a favourable position. It always picks them up with the hooks lying in the one direction, the fact of the matter being that the star is too near the wall of the kettle to allow any hooks to catch on behind the arms. This expert angler places the hooks, one by one, in the race-way which leads to the nozzle of the machine, and down this passage they go in regular regimental style. The machine punches a hole in the leather, places the hook in position, and clinches the back, thus fixing the hook securely in its proper place.

The fixing in of eyelets in lacing boots is accomplished by somewhat similar machines, but as eyelets have no convenient hooks, the fishing arrangement is replaced by a vibrating box, which shakes the eyelets right side up and drops them into the race-way.

Another point of interest is that when these uppers for lacing-boots come to be placed over lasts for the purpose of shaping them when fixing on the soles, the boots will require to be laced. It would be what the Scotchman calls "a driech (*dry*) job" to lace up the thousands of boots which pass through this department every day. A hard-working little machine undertakes the lacing, and for the sake of economy uses string in place of bootlace. This machine not only puts the string through the eyelets, but it ties a knot and cuts the string. The machine does all this in less time than it takes to tell, but although it is always in a hurry, it is not like the hurried schoolboy who fastens his bootlaces in any sort of knots, regardless of the fact that he will have to undo the same knots later in the day. The machine ties a respectable bow-knot, which, while remaining fast, may be pulled out very easily when desired.

While the workers and the machines in this department have been busy making a great variety of uppers, the departments downstairs have been busy also preparing the soles and heels to suit these same boots. The cutting out of the soles and heels is done by heavier and simpler machines than those now used by the clickers for cutting the uppers.

Of course we find a great variety of boots being made up here; some very heavy ones for carters, miners, and other workmen. In these the soles are fixed with wire nails or screws. It will be of greater interest to follow the making of what the Irishman would describe as "a hand-sewn boot made by machinery." No such paradox is used in the trade, this style being known as *welted boots.*

The first process of interest will be to get the uppers drawn tightly over the last. These have been placed loosely in position by hand, and the *insole,* or inner layer of the sole, has been fastened to the last by a couple of tacks. Those of us who have watched some village cobbler at his work will remember how he had to exert himself considerably to get the upper drawn over the last very tightly. The cobbler used a pair of pincers, with which he gripped the edge of the upper and pulled it over, little by little, all the way round, tacking it as he went, and then going over it again till he had it to his satisfaction.

The *pulling-over* machines do all this just as well as the experienced cobbler, and in a mere fraction of the time. We find one machine equipped with three pairs of pinchers, one in position to grip the toe of the upper, while the others take the sides. These three pairs of pincers act simultaneously, and when the boot is placed in position they do not only pull the upper over on to the insole, but hammer in five tacks to keep it in position.

The heel part of the upper is then drawn over by hand and fastened in a similar fashion.

The upper is by no means in its proper position yet; it must be drawn over very tightly, and then fixed in position for sewing it to the insole. It was in this final pulling over that the cobbler showed so much skill in giving exactly the right twist of his pincers as he passed from the toe to the side and then to the heel. But the automaton under the guidance of its master—the workman—does all this skilled man's work. One pair of pincers makes all the necessary motions, bracing a wire tightly round the edge of the toe part, putting tacks down the sides and round the heels. The tacks along the sides have to come out later, so the machine very wisely forbears driving these home, leaving their heads standing well up, so that they may be withdrawn easily, but the tacks around the heel are to be permanent, so it drives them well home.

When you are told that this machine is known in the trade as *the nigger*, you might guess a long time before finding the reason of this christening. You might suggest that it was because the machine was black, although, as a matter of fact, it is no blacker than other machines. Someone might suggest that it was because the machine "worked like a nigger," but the real reason is because it was invented by a "nigger." Although the machine has been greatly improved, it was a coloured man who invented the original machine.

Everything is now in position for stitching on the *welt*. The welt consists of a narrow strip of flexible leather, and the workman places this in position around the sole, while a heavy sewing - machine with a curved needle stitches the welt and the upper to the insole. The needle avoids all the tacks, and it does its task so expeditiously that it can do as much work in one minute as a cobbler could in one hour. This is a great deal better than the boast of *John Grumlie*, that "he could do more work in a day than his wife could do in three," for one day's work of this machine would be more than two months' hard work by the cobbler.

After other machines have given the heavy outer sole its proper shape, and fixed it on the boot with rubber solution, another heavy sewing-machine is used to stitch this on the welted boot. When the cobbler did this, he pierced the hole with an awl and then passed his bristle through the whole thickness at one time. This sewing-machine is also equipped with an awl, which prepares the holes for the needle. It will be remembered that the very first practical sewing-machine was made on the same general principle as this, but the pioneer machine only made a chain-stitch, whereas the modern machine makes a lock-stitch, and in other respects it outdistances its ancestor.

The last process which will interest the general reader is the heeling. Heels vary from the sensible and comfortable one-inch, to the unreasonable and presumably uncomfortable three-inch height. Everyone knows that the heels are built up of numerous layers of leather. These pieces are nailed loosely together by machinery, and then subjected to a pressure of several tons in a mould. The object of this is to compress the heel and also to give the top of it that hollow shape in which the wearer's heel rests. When this machine has done its task, it shoots the finished heels into a basket.

We are sure to be attracted by the automaton which nails the heels to the boots. It has a large stock of nails, for it has to drive no less than fourteen nails through the heel and sole at one stroke.

In the finishing department there are crowds of little machines, each doing its appointed task. Some are cutting and polishing the heels and soles, but they are all very tidy workers, sending the leather-dust right out of the factory by suction-pipes.

It will be understood that I have omitted many intermediate processes, but sufficient detail has been given to command our respect for the automatic shoemaker.

We are not surprised to learn that most of these labour-saving machines are of American origin. It seems reasonable to suppose that America has been the natural source of labour-saving machinery, for the country has risen so rapidly that there would be a shortage of skilled labour.

CHAPTER XIV

MANUFACTURE OF POTTERY

EVEN uncivilized man could not fail to observe that moist clay was a substance which could be formed with ease into any desired shape. Such shaped pieces of clay, when dried in the sun, would become of a more or less permanent character.

Not only did the making of bricks of sun-dried clay exist in the remotest antiquity, but vases of baked earthenware were used in Egypt at the earliest period of civilization. A walk through the Assyrian Department of the British Museum in London impresses one with the very ancient origin of the potter's art.

During the time of the Roman occupation of Britain great quantities of the rougher kinds of pottery were manufactured, of which vast accumulations have been discovered in some parts of England, while in other parts Roman kilns, potters' tools, and finished vessels have been unearthed.

The earliest forms of pottery-ware were unglazed, and therefore more or less porous, but the glazing of these was practised by the Egyptians as early as 500 B.C.

As late as the sixteenth century we find a Frenchman—Bernard Palissy—spending years of strenuous effort in endeavouring to discover how some Italian pottery had been enamelled. Palissy became so absorbed in his quest that he allowed his wife and family to come very near starvation, and in order to keep his experimental furnace going after his faggots were exhausted in what must be his final attempt, he broke up his garden-palings and the trellis-work supporting his vines. Finding these still insufficient, he smashed every piece of furniture in his house for firewood, ultimately breaking up the very floors and window-frames. This desperate final attempt fortunately proved to be successful, although his furnace burst and spoilt all the pottery-ware by fragments sticking to it. Yet he had proved that his mixture was right; he obtained financial assistance from a nobleman and the patronage of the King, and the enamelled ware of Palissy became famous. Though fortune now smiled upon him, he had to be sent to Paris by the King, at the time of the Reformation, in order that he might escape popular prejudice, but when eighty years of age he was accused of heresy, and placed in the Bastille, where he died in 1590. His desperate efforts, however, had given the French potters an enamel which led to a great national industry.

Even up to the middle of the eighteenth century only the coarsest kind of pottery-ware was made in Great Britain, and the potteries were in a very primitive condition. All the finer pottery-ware was imported from the Continent. At this time there appeared one whose name is well known—Josiah Wedgwood. He was the son of a potter, but his early experiences were not encouraging. His father died when Josiah was still a boy, and the little fellow, very shortly after this, had to lose a leg through a disastrous attack of smallpox, so that his was an uphill fight. Fortunately he had an artistic taste, and was able to devise fanciful shapes for pottery-ware, which in time earned him some fame. The one disadvantage against which Wedgwood had to contend was that the British clay was very coarse compared with that of the Continental ware, so that Wedgwood's finished articles did not have the same elegance as those of his rivals. By repeated efforts Wedgwood was able, by mixing flint powder with certain clays, to produce a material which became white when exposed to the heat of the furnace, and having discovered a convenient means of covering the articles with a transparent glaze, he succeeded in turning out earthenware as good as was imported from the Continent. This discovery not only brought a fortune to himself, but laid the foundation of that great national manufacture with which this chapter deals.

It is of interest to note in passing that while the primary question with the manufacturer of to-day is "Will it pay?" Wedgwood's chief concern was how to turn out the very best article that could be made, his last thought being whether it would pay him or not. Many would prophesy financial ruin to any man of such principles, but we know that with Wedgwood it was otherwise. He invented many different kinds of ware, and one of these so pleased Queen Charlotte that she

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A NOVEL SYSTEM OF CONCRETE CONSTRUCTION

When the complete side of a large house has been moulded in concrete, it is then raised bodily into position, and the other walls are added in the same manner. In the upper illustration a man is seen finishing off one of the windows before raising the wall.

commanded that it should be called *Queen's ware*, while its inventor received the title of *The Royal Potter*.

The old Scriptural saying, "As clay in the hands of the potter," gives us a most vivid analogy of plasticity. We have seen the little urchin sitting on the pavement while he shapes his ideas in moist clay. Scotsmen will remember the story of the great Norman Macleod, a powerful preacher and a humorous writer. He tells how he was passing along the street one day, and finding a little fellow busy with clay, or "muck," Macleod asked him what he was making. When the boy informed the minister that he was making "a kirk" (church), the following dialogue took place: "Where's the steeple?" "There" (pointing to a match). "Where's the pulpit?" "There's the poopit" (pointing to a hole in the ground). "Where's the minister?" "Oh—ye see, we're rin oot o' dirt. Here's Airchie comin' wi' a bit."

Those of us who have any recollections of visiting potteries in our boyhood will picture the potter sitting, as of old, in front of a revolving disc, and shaping each vessel with his hand, but the *thrower*, as he was called, has disappeared from most modern potteries. His place is taken largely by young girls, some of them fresh from school, the process being now practically automatic. But it will be of interest, before watching the modern pottery worker, to see how the material is prepared for her.

From what we have noted already in connection with Wedgwood's achievements, it is obvious that the potter cannot use ordinary clay as it is dug out of the earth. And so we are not surprised to learn that there are several ingredients in the prepared clay. The chief component is *ball clay*, or *blue clay*, which, by the way, is of a yellowish colour, despite its paradoxical name. There is plenty of this clay to be found in the South of England, and it is despatched to the pottery in its natural state.

The second ingredient is *china clay*, which is dug out of open mines in Cornwall. As this clay is really a decomposed granite, it contains a good deal of hard matter which is not plastic, and this has to be extracted. The material is practically dissolved by running water at the mine, the sediment is allowed to settle, and the pure clay is drawn off, leaving behind about three-quarters of the original bulk in the form of sand and silica. The pure clay is then dried and cut into lumps for despatching to the potteries.

Besides finding large stores of these two clays at the pottery, we notice also great heaps of stones, which we are informed have been gathered on the shores of Calais, while other similar heaps come from the Dover shores. These hard flint stones have to be calcined, and afterwards ground down to a fine powder. The purpose in putting these in the clay mixture is to prevent it from shrinking and also to give it a white appearance.

Another part of the pottery ground looks somewhat like a builder's yard, for there are heaps of boulders having the appearance of granite. This stone has been brought from Cornwall, and, when it reaches the pottery, is ground down to powder, whereupon it is ready for mixing with the clays and the powdered flint.

The requisite quantities of these are weighed out and thrown into a large tub containing water, to which is added a small quantity of cobalt, to counteract the yellow colour which would otherwise be produced by the oxide of iron present in the ball clay. Here these are thoroughly mixed by a revolving propeller, and the liquid mixture is then run off into a large cistern. At this stage the mixture is not unlike thick cream, but of a deeper colour. The outsider is not accustomed to think of clay in a liquid condition, but we must remember that when in this state it is mixed with a large proportion of water.

Before getting rid of the water is the time to dislodge any impurities from the mixture. One point of interest in this connection is the manner of extracting the iron contained in the mixture. The presence of iron particles is due to the ball clay, which contains iron, and which, it will be remembered, was despatched to the pottery in its natural state. Everyone knows that a steel magnet will attract small particles of iron towards it, but these must be very close to the magnet before it can attract them. The liquid clay, in passing from the cistern to another tank, is made to flow along a narrow trough in which there stands a small regiment of horseshoe magnets. As the liquid passes out and in among the legs of these magnets the particles of iron are entrapped and cling to the magnets.

The liquid clay is now free of those iron particles which would have caused specks in the finished articles if allowed to remain in the clay. The mixture still contains a good deal of grit and dirt, which must also be removed. This separation is effected in the same manner as that in which a workman separates stones from sand, by shaking it trough a riddle or sieve. The sieve in the present case is exceptionally fine. There are no less than ten thousand holes in each square inch; finer than fine muslin, and yet made of phosphor-bronze metal. To force the liquid clay to pass through this very fine sieve it is rocked from side to side very rapidly and violently by the sifter, which is driven by power.

After passing through the sieve, the liquid clay is collected in another cistern. The puzzle now is how to get rid of the water in which the particles of clay seem to be so permanently suspended. Of course this could be done by heating the liquid and driving off the water in vapour, leaving the solid particles of clay behind; but to evaporate all the water would be both slow and costly. This plan was adopted at one time in potteries, but only for want of any better plan. The present method is analogous to the cook's plan when making jelly. We have boyhood recollections of a sort of inverted fool's cap of flannel, into which the stewed fruit was poured, so that the liquid leaked through the walls of the jelly-bag, and dropped into a basin, while all solid fruit and stones remained in the bag. In the pottery the refined liquid clay is pumped up from the cistern, and is forced through a pipe into the clay-machine. This machine has a number of branch arms, to each of which is attached a long-shaped bag of fine cotton cloth. The shape of the bag is not unlike an extra long knapsack. The liquid clay is forced by the pump into these bags, which are supported in wooden partitions. Only the water can pass through the walls of the cotton bags, so that the particles of clay remain in the bags. When the machine is full the supply is stopped, and the bags are withdrawn. The solid clay is now removed from its bag in the form of a long flat slab, which is then rolled up and handed over to undergo one other process. This is necessary, because the clay has got a quantity of air mixed up with its particles, causing air-holes, which must be got rid of. This is attained by the last process, in which a machine, having revolving knives, cuts or minces the clay, and then compresses it into a solid mass. The solid clay leaves this machine by a large rectangular orifice in the form of a thick bar, which is thereupon cut into lengths suitable for carrying over to the factory, where it is to be shaped into cups, saucers, plates, and other useful articles.

It is here that we used to find the *thrower* at work. He would throw a lump of clay upon the centre of his revolving disc, and in a moment we saw a cup or some stately vase rise up under the gentle guidance of his skilful fingers. He would form one vessel, and then for our amusement he would press it up into a shapeless lump again, and in another moment give it a totally different and beautiful form.

As remarked already, the experienced *thrower* has disappeared from most modern potteries, and we find his work being done by girls. The explanation of this change, as, in all similar cases, is to be found in the word *machinery*, but in the present case the so-called machine is a very simple one. It is merely a revolving spindle, to the top of which is attached a metal bowl, capable of holding a plaster of Paris or stucco mould. It is merely a convenient means of revolving the mould at high speed. The young girl takes a lump of the prepared clay and throws it into the mould, which she then places in the revolving metal-holder. The particular mould which she is using is shaped in the inside to the outlines of a cup. As the clay and mould revolve she brings down a lever, to which is attached a simple metal tool that enters the hollow mould.

In order to understand the function of this tool it will be well to see how its shape may be arrived at. Suppose we were to make a thin metal partition which would stand upright in the centre of a cup and would divide it into two equal compartments; suppose we forced this piece of metal into the revolving mould, we should clear away all the clay from a space equivalent to the inside area of the cup. As the mould and the clay are revolving rapidly, it is obvious that were we to use only one half of the metal tool, holding it in its proper position, the same result would be obtained. This is the kind of tool the pottery girl has attached to the lever. The edge of the tool does not fit close to the inside wall of the mould, or the clay would be entirely removed. If it is set very close to the side of the mould, only a thin layer of clay will be spread out upon the revolving mould, while, the farther away the tool is, the thicker will the clay wall be.

In the making of a cup the cutting tool is set so as to form a wall somewhat thicker than required, for when the soft clay cup is removed from the mould, the outside of the cup is rather rough, although the inside has been smoothly finished by the tool. Before removing the cup from the revolving mould the girl touches the rim with a wire, which cuts away any clay projecting up above the mould.

The roughly-formed cup is then subjected to a moderate heat to dry it partially. It is next handed over to another girl or boy, who places it over the shaped end of a horizontal revolving spindle. Here it is treated just as wood is treated by a wood-turner. While the clay cup revolves rapidly, a sharp tool is brought to lightly touch the surface and remove all irregularities. At the same time, any further turning required in the shaping of the outside of the cup is done by contact with simple tools.

The cup is now complete, except that it has no handle, and it is a long cry back to the time of our great-grand-mothers, whose cups without handles are treasured by us as curios. The clay cups are now passed along to a man who is called a *handler*. Before watching this man at work it will be well to remark that while very young girls are engaged making cups, older girls are employed where the larger articles require heavier moulds, while such articles as wash-hand basins are made by men.

We now turn our attention to the *handler*, and we are somewhat surprised at the very simple manner in which the handles are fixed to the cups. Some clay is forced through an orifice, and comes out in the form of a long, round, or oval flexible rod. This is then cut into definite lengths according to the length of the handle required. The handler picks up these little straight pieces one at a time, and, as we used to say when we were boys, "it is all done by the turn of the wrist." In the present case this description is perfectly literal, for, catching one end of the straight piece in either hand, a sudden turn of the wrist and the handle lies before us, looking rather like a magnified mark of interrogation.

But how is this handle to be securely fixed to the cups? We can see no signs of glue or stick-fast stuff at hand. We watch the handler as he sits with a large number of cups and prepared handles before him. He picks up a cup in his left hand and a handle in his right hand, and, merely dipping the two ends of the handle into a solution of water and clay, he places the handle in the desired position on the side of the cup. A gentle pressure at both points where the handle touches the cup, and it is fixed. As the handler has probably bruised the shape of the cup slightly, he gives the inverted cup a gentle tap on a shaped block, which stretches the mouth of the cup into its regular shape once more. The cup may be lifted by its handle the moment it has been secured in the foregoing fashion. However, all ware has to be kindly dealt with until it has passed through the firing process.

It may be that the handle is desired to be of an ornamental character, in which case it is made in a complete mould, after the manner in which we made leaden bullets in our schooldays. The mould, containing a deep groove of the shape required, is opened, and clay is inserted in the one half-mould. Sufficient clay is used to fill the other half-mould when it is closed down upon the former. The pottery worker gets some exercise in firmly pressing the one half-mould against the other.

When the mould is opened later, the handle is complete, and only requires a little paring along the rough line occurring at the join of the two moulds. These cast handles are fixed to the cups or other articles in the simple manner described already.

A flat plate or saucer could not be made very conveniently inside a revolving mould in the manner in which we saw a cup being made. The method adopted in making plates and saucers is to flatten out a piece of clay somewhat larger than the plate or saucer desired. These cakes, or "bats," are made of a uniform thickness in a very simple manner. A girl throws a lump of clay on to a revolving disc, then, touching a large metal button projecting in front of her bench, she causes a lever to descend slowly over the revolving disc. She has merely to press the button to bring the lever into action. This descending lever carries a flat tool, which depresses the revolving clay very gradually, and flattens it out to the required thickness. To alter the thickness of these flat cakes it is only necessary to raise or lower the position of the tool upon the supporting lever. When the girl has made a number of these bats, a man places one of them upon the outside of a revolving mould. The mould looks just as though an inverted plate or saucer had been pressed down upon it when it was soft, and left the outline of the inside of the plate or saucer. The man then brings down the lever of his machine, to which is fixed a specially shaped tool. This tool, about one inch in breadth, is shaped to the curves corresponding to the outside of the plate or saucer. As the clay revolves upon the mould, he gently presses down this tool upon the clay, causing it to take the outward shape of the plate or saucer. And so we see that there are two methods of moulding by machinery, these being described as inside and outside moulding.

One method of making jugs is by means of moulds after the same manner as the ornamental handles are made. We watch the *Presser* making a jug. He takes two half-moulds, each representing one side of the jug, and after battening out two cakes of clay of the required size and thickness, he presses one of these into each mould. He then closes these two half-moulds with the shaped cakes of clay adhering, face to face, so that they form the complete side walls of a jug. Having clamped the moulds firmly together by slipping a leather band around the waist of the complete mould, he sets it firmly down upon a clay bottom piece, which he has prepared upon an outside mould. These three moulded pieces all unite together, but, in order to smooth the joins inside, the man gently spins the mould and its jug around on a hand-driven disc, while with his right hand he presses upon the inside of the jug. Some paring or trimming is required on the outside as before, after the article has been partially dried in a stove, and when the handle has been added, the jug is ready for the firing process. This method of making jugs by hand is now being largely superseded, machinery being adapted for manufacturing them, after the same manner in which cups and other articles are made.

Having gained some idea of the processes by which the pottery-ware is given any desired shape, we find the *kiln-men* carrying away the semi-soft articles to be fired. A number of articles are placed in what is termed a *seggar*, which is much simpler than its name might suggest. A seggar is merely a rough fire-clay tub of oval shape, which we may see being made in another part of the pottery. When a seggar is filled with a variety of articles, the man places it upon his head, and carries it to the kiln, which, as is well known, is pronounced as though it were spelt *kill*. A little girl of five said to me the other day that she thought people were very unkind to little girls to make TON pronounce *tun* when TONIC was *tawnick*. However, the pronunciation of the word *kiln* will not affect the heating property of these, and that is what we are concerned with at present.

These kilns are large cone-shaped brick buildings about twenty feet in height and eighteen feet in diameter, so that their capacity is very great. These pottery kilns are familiar sights in many parts of the country. The filled seggars are placed in these kilns, being built up one on the top of the other till the whole space within the kiln is filled with them.

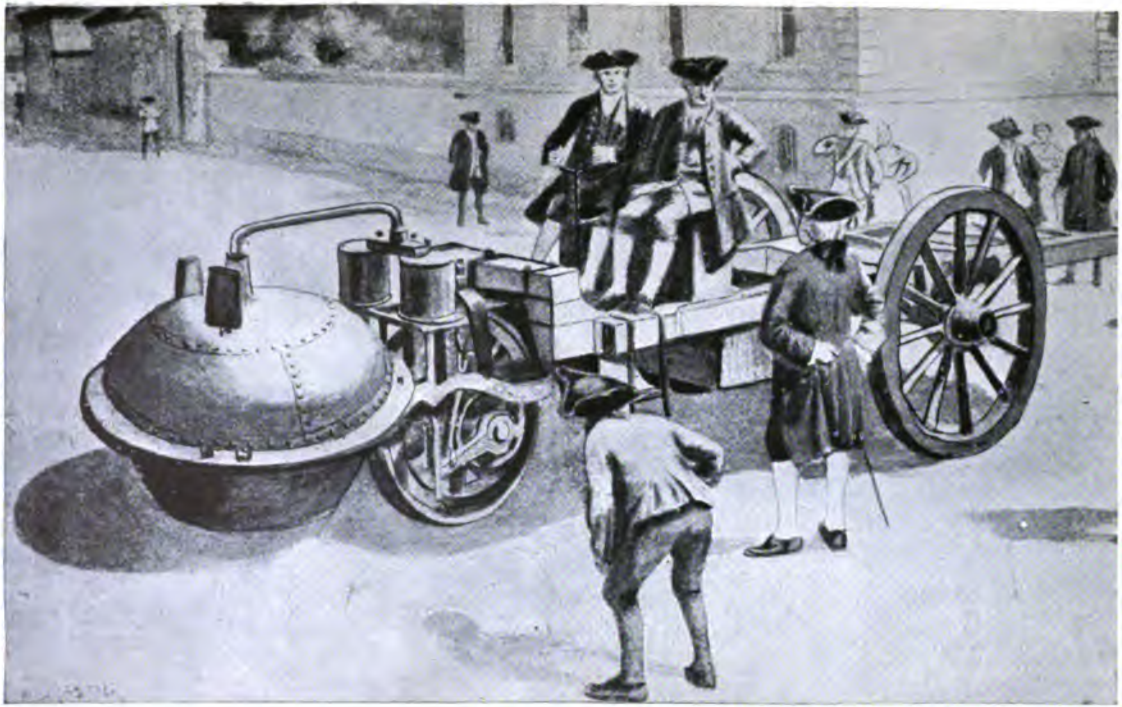
When the kiln is full the door is built up with bricks, and the firing is commenced. The temperature is raised gradually until the whole contents are white-hot. This heat is maintained for two days and two nights, and the heat is so great that when the fires are withdrawn it will take the kiln and its contents about forty hours before it can be drawn.

When things have become cool enough to handle, the door of the kiln isunbuilt and the seggars taken out.

The articles are then said to be in a *biscuit* condition. They are quite hard, and when laid one upon another they clatter in a way they could not do before the firing process. The articles have not the fine smooth appearance which they possess when they reach our homes. Indeed, they would be only a worry to the housewife in their present condition. On one occasion when a pottery stock was being sold off someone bought a large quantity of plates in this *biscuit* condition. These were taken by hawkers and sold in the streets to the would-be economical housewives at a great bargain. While the purchasers could not complain that the prices asked were exorbitant, they had a sore disappointment when it came to washing up. It was quite impossible to remove the grease and dirt from the pores of the wares.

The next process, however, is to ornament the plate or other article, and there are several methods of doing this. A simple design may be cut on a sponge, which, when dipped into colouring matter, can imprint the design upon the surface of the vessel. The girls and women become very expert at this, each showing some individuality in the manner in which she joins up the repeats of the design to make a complete figured band.

In another department we find a regular engraving process. The design is engraved upon a flat copper plate, and the printer spreads colouring matter over the engraved plate. When cleaning the colouring matter off the surface he leaves it only in the grooves or lines of the design. He then applies a sheet of specially prepared tissue-paper to the copper plate, and passes these through a pair of



By permission of THE FIRST STEAM LOCOMOTIVE *Messrs. Butterworth & Co.*

This primitive locomotive ran on the streets of Paris sixty years before the date of George Stephenson's famous "Rocket." The locomotive represented above was invented by Nicholas Cugnot in 1769, and although it could not go as fast as a man could walk, it is of special interest in being the first steam locomotive of which we have any record.

rollers like a mangle. When the paper is removed we find that the coloured design has been transferred to it. The process so far is exactly that used in the printing trade. These design papers are then cut up as required, and simply pressed face downwards upon the cups or other articles upon which the design is desired. After time has been allowed for the colour to dry, the articles are washed so that the tissue-papers fall off, leaving the coloured design on the surface of the article. In some cases coloured bands or gilt lines are added by hand in the painting department.

In addition to these methods of ornamenting pottery-ware, it may be mentioned that special transfer-papers are sometimes bought by the manufacturer, and these look very similar to the old-fashioned transfers we dabbled with in childhood, sometimes beheading a King in our endeavours to transfer his image to our scrapbooks. Another method of adding colour to the ware is to squirt or blow it on with one of those compressed-air machines which one sometimes sees at exhibitions, ornamenting picture postcards and other articles.

Now that we have successfully ornamented the ware, how are we to protect it against the continual washing and rubbing up of the careful housewife? Of course, if we were to place each article in a glass case, it would be all right, and this is really what the manufacturer does, only the glass case fits so closely to the article that it becomes part and parcel of it.

Before this glazing process is commenced all the printed or painted articles whose colouring matter contains oil must undergo a few hours' firing, in order to drive out the oil, for the glaze will not adhere to an oily surface. Articles such as the sponged ones and any others upon which only water-colours were used do not need this extra firing.

Now we come to the glazing process. We need not trouble with the ingredients of the glaze further than to notice that borax is the most important, and that the complete mixture, when fused and run off into water, is practically crystalline pieces of fused glass. It is then placed with water in a mill to be ground and reduced to a very fine powder, the grinding process occupying several days. The resulting liquid is not unlike the liquid clay in appearance.

The liquid glaze, after being sieved, is placed in a large tub, and a man dips each article into it in turn. This does not enhance the beauty of the printed ware; the cups and other articles look as though they had undergone a complete whitewashing. The men who take charge of the firing to which these are to be subjected carry them off and pack them carefully into seggars as before. But one article must not be laid upon the top of another, as in the first firing process, for the covering of glaze is about to be fused, and the melted glass, on cooling down, would cement all the articles together. It is necessary, therefore, to separate each article from its neighbour, but as they must rest on something, the best we can do is to let them rest on as few points as possible, and the finer these points the better for the purpose. Three points of rest will keep the articles in a stable position, and so the firemen, when packing the articles into the seggars, place little *stilts* between them. No doubt we have all seen these little supports at some time or other, although we may not have heard their name or known the exact purpose for which they were used. These are little three-armed cross-pieces made of hard-fired clay, and on the end of each arm are two little points, one projecting upwards and the other downwards. The articles when being fired rest on these small points only. When the glaze melts and then cools, each dish will stick to the three little points upon which it rests, and also to the similar points of the stilt which rests upon it in supporting the dish above it. Fortunately, this is not a very serious matter, for in removing the articles after firing these little points simply break off and adhere to the plate or other article. These are chipped off by the *dressers* in the warehouse, and I doubt if one householder in a hundred ever notices the little marks which are still left. In finer ware other means of suspending the articles during this glazing process have been adopted.

The firing for the purpose of glazing is similar to that described in the *biscuit* firing, but in the glazing kiln care has to be taken to prevent smoke reaching the prepared articles while the firing-up process is beginning. To this end each seggar has a roll of soft clay placed round the top of its rim, and this enables the one seggar to act as an air-tight lid upon the one below it, thus lessening the damage from smoke. The firing in this case is almost as intense as before, but not so prolonged, taking less than half the time of the biscuit firing. When the articles are withdrawn from the kiln, their whitewashed appearance has been transformed into that transparent glaze which is common to all domestic pottery-ware.

In the foregoing pages I have preferred to describe the manufacture of common pottery-ware, as that gives one the general principle of all pottery manufacture.

CHAPTER XV

PAPER-MAKING

In the long ago, when man desired to give his thoughts some permanent form, he would carve signs, such as the figures of animals, plants, and other objects, upon the public monuments and other hard objects, or he would trace the outline of these upon papyri, wood, or sheets of stone. An eagle would stand for Aa, a heron for Ba, and so on. The Egyptians had about one thousand different signs, and by the reading of these *hieroglyphics* in modern times we have had thought transmitted to us direct from the ancients who lived five thousand years ago.

We may look upon the papyrus as the first direct ancestor of paper, and we see that the family name is discernible still. The Egyptians took thin layers of the papyrus plant, and laying these side by side so that they overlapped at the edges, and then laying other layers crosswise upon these, they built up a thick sheet, which, after being subjected to pressure, was dried in the sun. This is really the general principle of paper-making at the present time, only instead of dealing with layers of the plant we separate the fibres of which the plants are composed, and instead of waiting upon the slow action of drying in the sunshine we apply artificial heat.

When we were youngsters we were taught that paper was made of old rags, and if we have lived long enough this teaching was quite justifiable, for it is within the memory of some how the increasing demand of paper led to a shortage of rags. It was this that caused the paper-makers to turn their attention to vegetable substances suitable for the manufacture of paper. The esparto grass of Spain was found to prove a suitable substitute, and the bulk of modern paper is made of this and similar grasses. Of course the idea of making paper of vegetable matter was a very old one, having been practised by the Chinese as early as the commencement of the Christian era, while the Arabians were busy making paper from cotton in the seventh century. Rags are used now only for the best quality of papers, while wood is in great demand for the cheapest papers, as we shall see later on. Commencing with the cheapest paper and rising to the finest qualities, we find that wood, grass, and rags is the order of the day.

Our present object is to pay an imaginary visit to a modern paper factory, and to see exactly how paper is made in large quantities, to help to provide newspapers, magazines, and books at the present low cost, which brings them within the reach of all.

Looking at the stock of raw materials at the paper works, one might think that the owners were catering for the feeding of a regiment of horses, until one remembers that these haylike bales are the material for making paper. When we examine the esparto grass at close quarters we find it to be coarser than hay, and not unlike dried green rushes.

The first process is to open up this grass and free it of all dust. This is done by machinery, and an automatic carrier transports the grass along a trough to the boiling department. Here the grass is boiled in huge tanks for a few hours. It is necessary to get rid of everything except the fibres themselves, and to this end the grass is boiled in a strong solution of caustic soda. The result is that the previously hard stiff grass is now soft and flexible, and free from silica, which hard matter was one of the original ingredients.

At one time it was the custom for the paper manufacturers to empty the liquid from these boilers into the river on the banks of which the works stood, but the authorities objected to this because of the large quantity of caustic soda present in the discharged liquid. It therefore became necessary for the manufacturers to extract the caustic soda, and this additional expense was considered a hardship. It was found, however, that when proper means were adopted for evaporating the liquid and recovering the soda it really paid the manufacturer to do so. So now we picture the same soda atoms returning time and again to the boiler-house to assist in the preparation of more grass.

After the grass has been boiled it has still a greenish appearance, so it is necessary to bleach all the colour out of it. We cannot make any mistake about the bleaching department, for there is a strong odour of chloride of lime. While the grass is being bleached it is mixed with water and stirred round and round in a tank by means of a paddle which revolves, in an upright position, under a cover, after the style adopted on a paddle-steamer. This keeps the whole mass moving round the tank, and all the appearance of grass soon vanishes.

The white, frothy-looking mass is now in a fibrous condition, but any roots or hard bits must be extracted. For this purpose the semi-liquid is passed along troughs leading to perforated trays or sieves, through the holes of which the fibrous pulp is all drawn by a powerful suction-pump. This leaves any roots or hard bits upon the trays. During this process there is a good deal of water added, and the resulting liquid is pumped up to a machine which the uninitiated is almost sure to mistake for a paper-making machine, for it embodies some of the general principles of the machine which makes the paper, and towards which the material is gradually making its way through these preparatory processes.

The purpose of this machine under consideration is to get rid of the bleaching material which has been soaked into the fibres. The fibres have had a good washing by the clean water which has been added, so that it only remains to get rid of this water in which the fibres are suspended. The liquid is poured on to a large sheet of wire-gauze, which is kept moving along the machine in the form of an endless band. The solution of water and chloride of lime falls through the meshes of the wire-gauze, while the vegetable fibres are entrapped, and remain in a solid mass upon the top of the moving screen.

This carries them towards a pair of rollers, and on going through this mangle they receive sufficient pressure to remove the bulk of the water remaining in the mass. This fibrous mass is delivered at the end of the machine in one long web, which looks exactly like a sheet of finely woven cambric. Indeed, before one knows what the machine is doing, one is surprised to see the boys at the end of the machine handling this web without any care whatever, bundling it into a heap, regardless of a hundred tears. The last word of the preceding sentence, if pronounced *teers* instead of *tares*, would give to the sentence a meaning which is not intended to be attached to it, for it is a matter of unconcern whether the mass is torn or not; the purpose of the succeeding process is to tear up the whole mass.

The stranger sees no difference between this beating-up machine and the bleaching-machine, except that the paddle under the cover seems to be going very much faster. As a matter of fact, the more gentle paddle has been replaced by a sort of propeller arrangement, in which a number of revolving blades work between a series of fixed blades, and thus draw the fibrous mass asunder without breaking the fibres. The idea is very similar to the combing, or carding, of wool or cotton for spinning purposes.

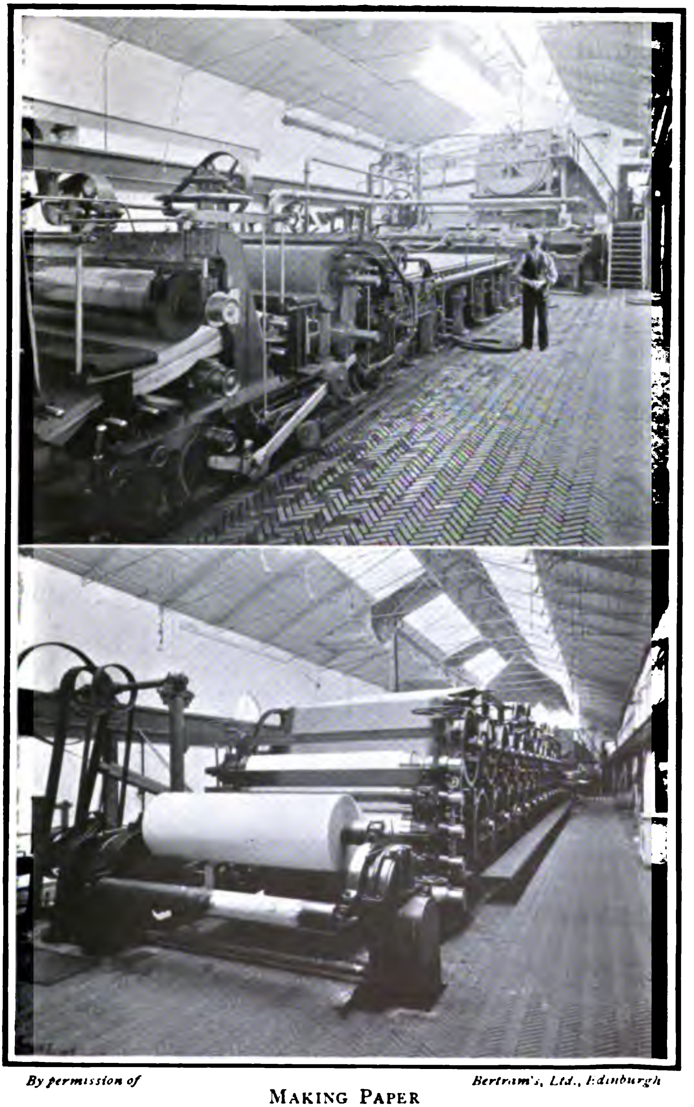
If the finished paper is to be tinted, as is the case with the bulk of writing-papers, the colour is added at this stage. Therefore we see different shades of coloured frothy masses moving round the tanks of these beating-up machines. I believe that if any novice were suddenly placed in front of one of these machines, without any hint as to the kind of works to which he or she had been mysteriously transported, the first guess would be either a confectionery or a bakery.

From these machines the dainty-looking mass goes down to large tanks on the lower floor, where a good supply of clean water is added. Of course no water enters into the composition of the paper, the function of the water being to act as a carrier of the vegetable fibres, which are the sum and substance of the paper.

From these tanks the liquid is pumped into very large "stuff-chests," or open tanks, in which mechanical stirrers keep the liquid on the move. These stuff-chests feed the giant paper-machines. If we considered the power-embroidery and the lace-curtain machines very large, we are bound to call these paper-making machines *giants*. Some of these machines measure three hundred feet in length, and weigh no less than five hundred tons each. Up to this point all the other machines have been busy preparing the material for these leviathans.

In Chapter XIII. we saw that it was impossible to have any one machine which would accept raw leather at one end and deliver complete boots at the other end. This giant machine, however, will accept the liquid from the stuff-chests at the one end and deliver the finished paper at the other distant end (see illustration facing this).

The bulk of the water which is carrying the vegetable fibres to this machine is got rid of as soon as it lays the fibres on a travelling wire screen, which is subjected to a rather violent side-to-side shaking on its journey. As the



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MAKING PAPER

The material from which the paper is to be made enters the machine at the distant end, a view of which is shown in the upper illustration. By the time the material reaches the other end of the machine, a distance of about 300 feet, it is in the form of a great roll of finished paper.

liquid leaves the stuff-chests it looks somewhat like water that has been poured into a milky glass. This liquid falls upon the travelling gauze, which is in the form of a very long endless band.

The mass of fibres which is deposited upon the travelling screen by the escaping water still contains a good deal of water which cannot be abstracted by this moving sieve arrangement. The fibrous mass is therefore passed under a roller, which squeezes some of the water out, and, if a design be cut upon this roller, the soft mass will retain the impression, which will give us the well-known water-mark in the finished paper.

The wet mass, in its long journey, next passes over suction-boxes, by means of which a pump sucks a great deal of water out of the substance. The resulting web, which is still moist, is now able to bear its own weight, and after passing through a mangle arrangement and other two sets of pressure rollers, it could be described as damp paper. If this were dried hurriedly, it would become stiff, but by drying it very gradually it will remain flexible. The web has therefore to make a prolonged procession over a whole regiment of hot rollers, a blanket of felt always coming in between the paper and the hot rollers. After going through this ordeal, the finished paper makes its exit at the end of the machine. But if the paper is required to have a polished surface, it has to make its way between a number of very smooth and heavy rollers before its final exit takes place.

One of the operators keeps an eye on the production of the machine, as to the quality, or rather the weight, of the paper. Sheets of a definite square measurement are weighed on a delicate balance from time to time, and if the paper is found to be too heavy, the speed of the machine may be increased slightly, so that the quantity of fibres poured on to a given area of the wire-gauze is reduced. On the other hand, if the paper is found to be too light, the rate of travel is decreased, to give the stuff-chests time to deliver more fibres on a given area.

When the finished paper makes its exit, it is in the form of a web about one hundred inches in width, and this is rolled upon a beam as it comes off the machine. It only remains to cut up the paper into sheets of various sizes. This is done very expeditiously by machines having knives, in the form of little circular discs, which do their work while the wide web of paper is unwound and run through this machine. The first cutting-machine merely divides the great web into webs of more convenient widths, each width going on to a separate beam.

During the dividing of the great web, the selvedges are cut off to leave a clean-cut edge. The waste paper from the selvedges is sent up to join once more in the making of another great web. As the fibres composing this waste paper have already gone through the straining and bleaching processes, they are allowed to join the new lot of fibres at the beating-up machine, and thereafter they become part of the common contents of the stuff-chests.

In order to cut the narrower webs into sheets, the webs are passed through a second cutting-machine, which not only has little circular knives, the positions of which determine the width of the sheets, but also a guillotine arrangement, which chops off the required length, so that the finished sheets are delivered at the end of this machine Dr. Guillotin, who proposed the adoption of this instrument at the time of the French Revolution, said of it: "Messieurs, I whisk off your heads in a twinkling, and you have no pain." It should be remembered that although this machine bears the name of Dr. Guillotin, it was in use in other countries before his time.

We have followed the grass from its arrival at the paperworks till it is ready for sending out in the form of paper suitable for writing or printing upon. It will be of interest to see wherein the difference lies between these good-quality papers and the cheaper papers, such as those used for the daily newspapers. We have seen already that wood is used for the cheapest form of paper, so that we are not surprised to learn that newspapers are made of wood.

The newspaper printers, whose work we shall consider in the succeeding chapter, require the paper to be delivered to them in long rolls, so that they can run the paper through their machines, and print it in one continuous length. Most of us must be familiar with the appearance of these great rolls as they are carted through our streets. It seems a common practice in London to use the transit of these as a means of advertising the particular newspaper into which the paper is to be made. It is not an uncommon sight to see such words as "Five miles of paper for the *Evening* ——," printed in bold type upon each of these great rolls. Many newspaper printers prefer the rolls to contain only six thousand yards, or about three and a half miles of paper, as these are as large as they can conveniently handle.

It is clear that before we can make wood into paper we must free the vegetable fibres of which the wood is composed, from the very close entanglement in which we find them in the trunk of a tree. To this end great trunks of trees are pressed firmly against revolving grindstones, while a copious supply of water is added. This operation takes place on the banks of the river down which the wood has been drifted from the forest.

When the water has carried the wood-fibres to a screen, through which the water alone can escape, the fibrous mass is pressed and dried, and then cut into sheets. These look not unlike very thick sheets of extra coarse brown paper, in which the fibres are arranged in a most irregular manner. It is in this form that the paper-maker receives his wood-pulp from abroad, and one might describe these sheets quite fairly as being paper, only in a very unrefined condition.

The paper-maker must save expense wherever it is possible in producing the vast quantities of paper for newspapers. This fact is self-evident when we consider that in some cases as many as twelve pages are contained in some halfpenny newspapers. The paper-manufacturer makes a good start in this direction by allowing the wood-pulp to omit all the preliminary processes preceding the beating-up.

The wood-pulp, as delivered, requires no boiling or filtering, and it is allowed to go without any bleaching

Having been beaten up, and then passed down to the tanks, in which a supply of water is added, the liquid then goes direct to the stuff-chests which feed the great paper-making machines. The paper is delivered at the other end of the machine in a web about one hundred and fifty inches in width.

This very wide web is cut up, as already described, into several narrower rolls, ready for the printing-machine. Some idea of the vast production of a single paper-making machine may be obtained from the following suggestion: If we were to put one week's production of newspaper rolls from one machine on a railway train leaving Glasgow for London, we could trail a continuous line of the newspaper width all the way to the Metropolis, and we should not have exhausted our stock even then.

When making high-class papers from rags, it is, of course, necessary to reduce these to pulp, and having freed the fibres, the processes of paper-making follow as already described.

It is interesting to note that we depend upon the fibres composing plants, and the coats of animals, for providing ourselves with clothing, and we use the same kind of fibres for producing paper upon which we may record our thoughts. In the woven cloths we first of all twist the fibres into thread, but this is not necessary in producing such fabrics as *felts*. In these cloths we depend upon the fibres clinging to one another in a higgledy-piggledy condition, and in paper we adopt the very same principle.

It may be remarked in closing this chapter that the paper-making machine of to-day is the same in principle as it was when invented about one hundred years ago, showing what a long-headed man the inventor was. A Frenchman—Louis Robert—is usually accredited with the invention of this machine, but a very similar machine was patented a year earlier by Joseph Bramah, a Yorkshire engineer, whose name is better known in connection with the hydraulic press which has been named after him.

CHAPTER XVI

THE MANUFACTURE OF BOOKS

If the monks of a few centuries ago had been told that, at some future date, books would be produced in thousands by inanimate machines, they would have thought, no doubt, that this was an idle tale. They were content to write each book by hand, and to spend much time in ornamenting every page.

There is no doubt that the starting-point of the evolution of printing is to be found away back thousands of years ago, when the ancients imprinted characters upon bricks, stamping the soft bricks with a prepared block.

Leaving the Chinese out of account, and confining ourselves to the evolution of printing in Europe, we find that simple drawings were cut out on wooden blocks, and used for printing from, in the thirteenth century. Then followed the engraving of written characters upon page-blocks, from which books were printed.

The invention of movable type was due to a German—John Gutenberg (or Gensfleisch)—who spent much time and money in trying to make printing type. With a knife he cut out the individual letters on pieces of wood, and then, strung them upon a piece of wire, in the order required to form words and sentences. With these Gutenberg obtained quite good impressions upon parchment, but his associates distrusted him, and brought him into trouble with the authorities at Strasburg, in which town he had been residing. He left in a penniless condition for his native town of Mainz, where he secured a wealthy goldsmith—John Fust—as partner in his printing schemes. The priests and transcribers became jealous of Gutenberg and Fust, but the latter succeeded in gaining their favour, while poor Gutenberg was dispossessed of his invention.

The first idea was to imitate the writing of the monks, and there is a story told of how Fust went over to Paris, to pass off his printed Bibles as manuscript writings. The King of France and the Archbishop of Paris, having each bought a copy from Fust, were struck by the similarity between the two copies, and became suspicious. They thought he must be a wizard, and so they proposed burning him, but Fust saved himself by confessing his secret. So the story runs, and whether it be true or not, it is obvious that the people would wonder how Fust could produce so many copies, and each an exact duplicate of the other.

It should be observed that Gutenberg and Fust invented metal type. They prepared *matrices*, or moulds, of the different letters, in which they cast the metal type.

When Fust's secret became known, many printing-presses were set up in Continental cities. About this time—the middle of the fifteenth century—an English merchant named William Caxton, was resident at Bruges. There fell into his hands an interesting French book, issued by one of these printing-presses, and Caxton was impressed with the "many strange marvellous histories" which the book contained. It occurred to him to translate the book into English, so that his fellow-countrymen might have the benefit of it. Caxton visited some of the German towns which possessed printing-presses and studied the art of printing. At the end of his translation of this French book he writes: "I have practised and learned, at my great charge and dispense, to ordain this said book in print after the manner and form you may here see; and is not with pen and ink as other books are, to the end that every man may have them at once." This information was for the English people, who did not possess a single printing-press at that date.

Somewhere between 1470 and 1480 Caxton returned to Great Britain and set up a printing-press within the precincts of Westminster Abbey in London. His first advertisement is of interest. It was evidently in the form of a circular letter, and set forth that if anyone wanted "emprynted after the forme of this lettre whiche ben well and truly correct, late hym come to Westmonster, in to the Almonesrye, at the reed pale, and he shal have them good chepe."

Caxton's example was followed by other men of literary acquirements, who became book-printers. With the spread of literature the demand for more copies of books became greater, but the printers worked away with their simple screw-presses, with which they pressed the paper against the types previously inked by hand. To try and cope with the growing demand for more books, the Earl of Stanhope made a printing-press which could print a whole sheet of paper, so that a number of pages could be impressed at one stroke. He improved the printing-press in other directions, so that the printer could turn out two hundred and fifty impressions per hour.

In 1790, Mr. Nicholson, the editor of the *Philosophical Journal* (London), took out a patent for a machine which embodied all the principal actions of a modern cylinder printing-machine. Nicholson did not carry his ideas into practice, but some fourteen years later a young German mechanic, Friedrich König, who had come to London, commenced making experiments with machines on the same plan as set forth in Nicholson's patent, which had been allowed to lapse.

Some ten years later (1814) it was proposed to John Walter, the proprietor of the *Times* (London), that he should adopt König's printing-machine for the production of his newspapers. It is to the credit of John Walter that, although he had lost already a considerable sum of money in assisting a compositor to work out the idea of a printing-machine which came to nothing, he was willing to give this second attempt a fair trial. This was no easy matter, as his printers threatened violence if any machines were introduced to interfere with their work.

Two of König's machines were erected in a building near the *Times* office, and these were driven by a steam-engine. It would have been folly to try and erect the machines within the *Times* office, as the feeling against the introduction of machinery was very bitter.

Early one morning in November, 1814, John Walter walked into the *Times* printing-room and astonished the men by telling them that the *Times* was already "printed by steam," and that if they should attempt any violence there was a force ready to suppress it, but that if they were peaceable, their wages should be continued to every one of them till similar employment could be procured.

These first two steam printing-machines turned out eleven thousand copies per hour; one machine printing the one side of the paper, while the second machine added the other side. Improvements followed very quickly, and a modern newspaper-machine can print both sides of fifty thousand eight-page newspapers in one hour. These modern machines cut the paper, fold it, and paste in the pages, handing out the complete paper ready for sale.

The steam-machine was soon adopted by the book-printers. As the demand for books went on increasing, it was found very inconvenient to keep great quantities of type set up for printing further editions when called for. Besides being inconvenient, it was troublesome, as types would become displaced, and would drop out at places. To obviate this difficulty, some printers ran molten lead in at the back of the types to fix them in position. Then followed the idea of saving the type to use over again, simply taking a casting of the types while arranged temporarily in the page-form for printing. This method is called *stereotyping*, from the Greek words *stereos*, solid, and *typos*, type.

THE MANUFACTURE OF BOOKS

I am indebted to the firm of William Collins, Sons and Co., Ltd., of Glasgow, for showing me the modern processes used in the manufacture of books on a large scale.

When the iron frame containing the set-up type comes down from the compositors, an impression is taken on papier-maché, which produces a perfect mould of the type. This mould is then placed in a heavy cast-iron box, and when a molten lead alloy is poured into this moulding-box, a clear impression of the type is reproduced in the form of a solid page. Whole sheets containing a number of pages may be reproduced in the same way. These are then trimmed up and made ready for the printing-machines, and the compositor's type is free to be taken down and used over again for other books.

It may be remarked in passing that, although it is found convenient to continue the setting-up of the type for books by hand, there are many clever mechanical compositors in use where rapid composing is necessary. As far back as 1776 efforts were made to increase the efficiency of the compositor. The first idea was to have types made with combinations of letters which are frequently repeated, but this made the type-cases too complicated, so that the number of errors was greatly increased.

The first mechanical compositor (1833) merely selected the letters by means of a keyboard, which freed the type in the case as required. While the type was thus arranged in the order desired, it remained for the operator to arrange the spaces between the words, an operation which is spoken of in the trade as *justification*.

A great forward step was made when the machines were deputed to undertake the duties of type-founder as well as those of the compositor. These machines are supplied with a gas-heated ladle of molten metal, and as the operator calls for the letters required by means of a keyboard, the machine casts the type by means of *matrices*, or moulds. One class of machine casts a solid line of type, while another class casts each letter separately.

In the most modern form of the single-type casting-machine a band of perforated paper controls the actions of the mechanical compositor. This perforated ribbon is prepared by means of a keyboard-machine, just as we saw the perforated cards were prepared for a Jacquard weaving-loom. In some composing-machines the perforations are made to act upon the controlling mechanism by means of compressed air, while an electric current supplies the connecting link in other machines.

One of the most interesting points about a modern mechanical compositor is the manner in which it reckons up how many of the words called for will go into a line, and the space required to be made between the words so that the line will be filled exactly. While the paper is being punched, a calculating device registers the thickness of the characters as they will be finally cast, and calculates the remaining space dividing it equally between the words. It is most interesting to watch one of the casting-machines at work under the control of one of these prepared paper ribbons. The machine makes no mistakes. It has all the matrices arranged in a flat plate, which it can move about in every direction with great speed. It brings each matrix into position for casting as required, adding the necessary amount of space at the end of each word, and handing out each line when completed.

It is even possible for a large newspaper office in the city to set up the type in a country town many miles distant. The perforated paper at the head office may be made to operate a special telegraph instrument which actuates the mechanical compositor at the distant office.

To return to the manufacture of books, we need not trouble much about the printing machinery, as almost everyone has a general idea of the process. Printing-machines are always in evidence at our great industrial exhibitions. Sometimes we find the type arranged on a flat carriage or table, which moves to and fro in the machine. As it runs forward it presses the type against a sheet of paper carried on a revolving cylinder. As the type-carriage moves back again the cylinder rises a little, so that it keeps clear of the type. On its way back the type passes under a series of ink-rollers, which re-ink the type before each impression is taken.

In another class of machine the stereotyped plate forms the cylinder, and it revolves continuously, producing a long succession of printings, such as is required in the production of newspapers by the mile. These rotary-machines are used also for printing certain classes of books where a great quantity is required.

In most printing-machines the sheets of paper are fed in by the operator, but there are some machines which undertake to feed themselves in a most ingenious manner. If one is working with thin sheets of paper, it is rather difficult to lift only one sheet at a time. After endeavouring in vain to separate the sheets with one's fingers, one blows a puff of air between the sheets to separate them. The self-feeding machine not only imitates this blowing of air, but it has little metal fingers which faithfully copy the action of an operator's fingers when handling the paper. A small roller imitates the movement of the human thumb forcing up the corner of the paper, and several metal fingers enter below this corner to hold down the remaining sheets while, by means of compressed air, the machine blows between the sheets and frees the top sheet, which is pushed forward by another set of fingers, so that the revolving cylinder may catch the paper and carry it to the type.

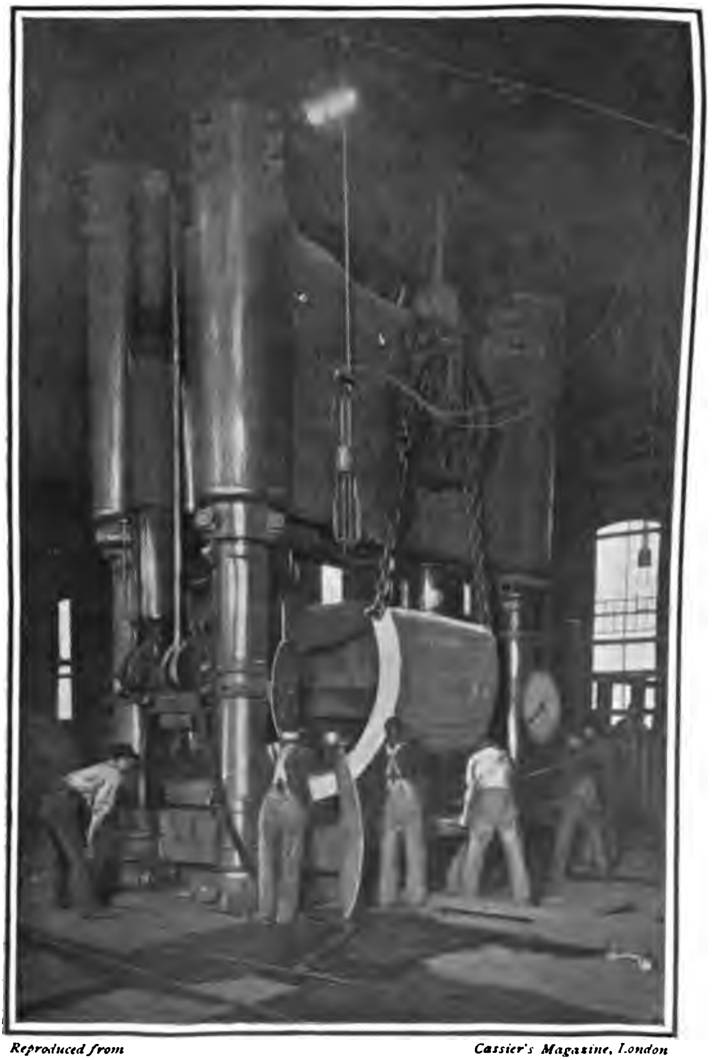
The printed sheets are handed over to another machine, which folds each sheet into page form. These folded sheets are built up in piles, and, when placed in a special guillotine-machine, the edges are all cut except on that side which is to form the back of the book. This machine can cut five thousand pages at each stroke.

Each of the original sheets is still distinguishable as its pages are folded together, and form, as it were, a pamphlet by themselves. These sections are all laid out in piles. The first pile contains the sections which have the first sixteen pages of the book printed upon them, while the second pile represents the second sheets of sixteen pages, and so on. A girl draws one section off each pile in very rapid succession, and thus places the pages of one book in their correct order. Piles of books are made up in this way, and these are checked by another girl, who can tell at a glance if any section is out of order. She merely looks at the small letter which is printed at the bottom of the first page in each section. If the reader turns to p. 17 of the present volume it will be observed that the letter B is printed below the last line; sixteen pages further on the letter C will be found, and so on at every sixteenth page.

These sections are then placed in a special sewing-machine, which stitches a string through the pages of each section, and binds the sections together in book form. Another machine compresses and rounds the back of the book preparatory to receiving the cover.

Other automata are busy making the covers, or *cases*, and it is interesting to watch one of these machines at work. The machine has pneumatic fingers, with which it picks up two strawboards which are to form the body of the case. The fingers lift these boards over to the centre of the machine just in time to lay them down upon the cloth covering which has been fed forward from the opposite end of the machine, having been thoroughly covered with glue on the upper side during its passage. As soon as the pneumatic fingers have placed the strawboards in position the machine deftly folds the edges of the cloth over the sides of the boards, and at the same time it cuts off a length of paper ribbon, which it pastes into the back of the case between the two boards, handing out the complete cases.

Another machine is deputed to paste the covers on the books. The coverless books are placed upon arms at one end of the machine, while the cases enter at the other end. Before they meet at the centre of the machine the



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A POWERFUL HYDRAULIC FORGE

Heavy plates of steel are bent into different shapes by the force exerted by those great hydraulic presses.

outside of the book has been automatically covered with paste, after which the machine places the case in position upon the book, and hands the article out quite complete. The finished books are placed in hydraulic presses, which subject them to a pressure of about two tons, so that the cases and the pages will lie snugly together.

Some idea of the enormous production of books at the present time may be gathered from the fact that this one factory could turn out two thousand complete books every hour.

The subject of preparing the blocks for illustrations has not been dealt with here, as I have explained the different methods very fully in another volume of this same series (*The Romance of Modern Photography*). It is interesting, however, to watch the workmen making duplicates of half-tone blocks which have been prepared directly by photography. The whole printing surface of a half-tone block appears perfectly smooth, but it is made up of a myriad of tiny dots, as may be seen by examining any of the illustrations in this volume with the aid of a magnifying-glass. It is surprising that these tiny dots can leave such a faithful impression upon the paper when treated as ordinary type in a printing-machine.

It would be quite impossible to make an ordinary mould from this block, in which one could cast a duplicate, but the same thing is arrived at in another way. The half-tone block, with its myriad of minute dots, is laid face down upon a perfectly smooth block of beeswax, the surface of which has been treated with graphite or black lead. These are placed in a hydraulic press and subjected to a pressure of about two thousand pounds to the square inch. The machine informs the operator, by means of a dial, the exact amount of pressure which it applies gradually, so that he can call a halt whenever he considers it necessary. When the copper block is removed, a faithful copy of its myriad of dots is left upon the wax. The idea in having the surface of the wax block covered with graphite is to render it a conductor of electricity for the purpose of electro-plating. The prepared beeswax impression is then placed in a bath filled with a solution of copper sulphate, and is attached to the leading-out wire of an electric circuit, while a plate of solid copper is attached to the end of a wire leading in the current from a source of electricity. The plate of copper and the beeswax impression stand apart from one another in the solution, but the electric current passes across from the copper plate to the conducting surface of the beeswax through the liquid. Whenever the electric current is turned on there is a commotion among the wandering atoms, or *ions*, in the copper sulphate solution. Some of the copper atoms in the solution are attracted over to the leading-out terminal, and attach themselves to the prepared surface of the beeswax, while the solution helps itself to more copper atoms from the plate of solid copper. This *electrolytic* or electro-chemical action gradually builds up a thin coating of metallic copper over the beeswax impression, which goes on increasing as long as the electric current is maintained. When the operator finds that the electro-plating is of sufficient thickness, he takes the beeswax out of the solution, and removes the newly formed copper plate which covers its prepared face. The surface of the copper plate is now an exact duplicate of the half-tone block which made the impression upon the beeswax.

It only remains to strengthen the electro-plated duplicate, or "electro," by adding more metal to its back. To this end the operator first of all places a sheet of tinfoil on the back of the electro, and in order to melt the tinfoil he has to expose it to considerable heat, which he does in the following manner: He begins by placing the electro face downwards upon a heavy iron girdle, after the manner in which the household cook does when baking scones. The operator has a source of heat close at hand, for the men who do the stereotyping already referred to have large metal boilers filled with molten lead. The operator lays his heavy iron girdle on the surface of the molten metal. The girdle does not sink, for the same reason that a piece of wood floats upon water.

The thin sheet of tinfoil melts very quickly, for the temperature is about six hundred degrees Fahrenheit. There is no fear of the copper melting, as it requires more than three times that temperature to fuse it. The electro has now got a tinned back, and it only remains to back this up with a sufficient thickness of type metal, after which it is trimmed up and handed over to the printing department. In this way the original half-tone block may be kept as a standard from which any number of reproductions may be made.

In connection with book illustrations it may be observed that one marked feature in the modern factory is the gradual disappearance of lithographic machines, with their separate blocks or stones for each colour, and the steady advance of the *three-colour process*, in which all the colours are produced by the overlapping of three printings. This process is one of the great achievements of photography.

CHAPTER XVII

MAKING ARTIFICIAL LIGHT

Of course we can only make *light* in the same sense as we can make waves in the sea, for light is merely a succession of waves in the all-pervading æther of space. But the means we have discovered for producing light are of interest to us.

It is quite an easy matter to produce artificial light by burning any combustible substance; we have only to start the chemical combinations which we call *combustion*, and the conflagration will proceed on its own account. Indeed, we know the great difficulty of stopping a fire as long as it can get at plenty of combustible material. A single match might set enormous forests on fire.

But our forefathers did not find it so easy a task to produce fire; they had to supply a good deal of personal energy to obtain even a tiny spark. Of course, when they had once set a fire agoing in the morning, they could obtain any number of other lights from it, until they let it die out at night-time. In the evening the careful housewife would make some *tinder* by charring a linen rag. This half-burnt rag was placed carefully in a tinder-box along with a piece of flint and steel. I wonder what the modern cook would say if, when she rose on a dark winter morning, she could obtain no light until she succeeded in producing a spark by striking a piece of flint and steel together, and causing this hard-earned spark to ignite the tinder? It might take only one minute, but it might take half an hour; indeed, a householder might be compelled to go and borrow a light from a neighbour at times.

Even when the spark was produced successfully, and the tinder ignited, there was no flame. The smouldering rag had to be carefully nursed until a brimstone match was lighted by it. These early matches merely served the same purpose as wax-tapers do at the present time. The matches were thin strips of dry pine-wood, about six inches in length, with pointed ends which had been dipped in melted sulphur in order to make them more inflammable.

This method of producing fire was, of course, a very great advance upon the *fire-drills* of the ancients. These depended entirely upon the friction between sharp-pointed piece of stick, which was made to turn quickly round while its point pressed against a socket formed in a flat piece of wood. Sometimes they merely rubbed the point of one stick to and fro in a groove formed in a second piece of wood.

We need not trouble about the ancient method of obtaining fire by focussing the sun's rays through burning-glasses, as that was not an ancestor of modern methods. We should not like to have to wait patiently till the sun shone before our breakfast could be cooked. There is no doubt that when the ancients prohibited any fire but "holy fire" being used for religious purposes, they referred to fire produced directly by the sun, and not that obtained by artificial means.

The younger generation is apt to forget that the use of the tinder-box, with its flint and steel, is not a very old story. Some old folk living at the present time have boyish recollections of watching the cook preparing tinder in the evening. Indeed, no advance was made until 1826, about which time several ingenious methods were adopted.

In order to appreciate the introduction of these, we may picture an old gentleman of that time having returned from a visit to London, and having brought with him one of the new "instantaneous light boxes." He takes from his pocket a small metal box containing some of the new matches and a small bottle of sulphuric acid. As the latter is not a very safe thing to carry about in one's pocket, a bundle of asbestos fibres was placed in the bottle, to soak up the acid or vitriol. Having uncorked the bottle, the old gentleman would take one of the little strips of wood, with its small head of pink paste, and dip this into the bottle, so that the head was moistened with the sulphuric acid; heat was evolved, and in a moment the head of the match burst into flame. The onlookers, who still had to work away with the flint and steel, would envy the possessor of this "instantaneous-light box." While this was a great advance, it was found that in damp weather the sulphuric acid absorbed so much moisture that it lost its chemical properties, and the matches failed to ignite, so people set about to invent something better.

In the next method we have a very direct ancestor of the modern match. Small strips of wood had their ends prepared with an inflammable paste, which could be ignited by friction. The plan adopted was to draw the head of the match between a piece of folded sandpaper. These were called *lucifer* matches, and the ease with which they were ignited made them popular immediately.

A few years ago an old clergyman who was my neighbour in a country district told me that he could remember going down to the village to see the first box of lucifer matches which reached the district. Someone had brought the box from London. There were only a few matches in it, but it had cost several shillings. The old hand-loom weavers and other village worthies gathered round to see the happy possessor of this novelty ignite one of his valuable matches by drawing it through the folded sandpaper.

These lucifer matches required some pressure of the sandpaper to cause them to ignite, but it was found that if a little phosphorus was introduced into the composition of the head the match would ignite when merely rubbed against a piece of sandpaper or any other hard object. These phosphorus matches were called "Congreve matches," and by means of these fire and light were produced more easily and conveniently than had ever been the case previously.

As there is the danger of phosphorus matches being ignited accidentally, it was suggested to separate the phosphorus from the other ingredients of the match-heads. This was done by mixing the phosphorus with fine sand, and making that the friction-surface on the outside of the box. Bryant and May have been the pioneers of these *safety matches* in Great Britain.

The original phosphorus matches were sold in boxes of fifty for half a crown, or more than a halfpenny each. If we had to buy matches to-day at two a penny we should be more careful of them. Nowadays one may buy hundreds of matches for a penny, so that it is only the proverbial Scotchman who could be credited with any strict economy in this direction. I remember a cartoon appearing in one of our journals within recent years poking fun at the poor Scotchman. A Scotch workman was depicted, sitting in a smoking compartment of a railway carriage with his pipe in his hand and an anxious look upon his face as he addresses the other occupants of the compartment. "Can ony o' yez lend us a match?" he inquires. After repeating his inquiry, and still getting no response, he says: "Suppose I'll jist hae to use yin o' ma ane."

It will be of interest to see the modern method of manufacturing matches. A glance at the London factory of Bryant and May will explain how we get such a large quantity of matches for a single copper.

A modern match-making machine accepts solid blocks of pine-wood, and after converting these into matches, it will place them in boxes, and hand these out all ready for use.

When the small block of pine-wood enters the machine, a cutter cuts forty-eight matches at a single stroke, and as it makes about two hundred strokes every minute, a simple calculation tells us that this one machine will produce over half a million matches every hour.

The machine not only cuts these wood splints, but it places their ends into rows of holes in a travelling screen, which is in the form of an endless band. The wood splints hang down from this perforated screen and produce quite a hedgehog effect. As the screen moves along it dips the free ends of the splints into a heated bath of paraffin-wax, which renders the tips of the wood more combustible.

The next operation is to apply the ignition paste to form the heads. If the ends of the splints were drawn through a bath of this semi-solid liquid, they would gather the bulk of the paste on the advancing side of the match, and the heads would be all one-sided. To obviate this the wood splints do not dip into a stationary bath. The paste is picked up by the surface of a revolving roller, so arranged that as the wood splints dip into the paste upon the roller the paste is being carried forward at the same rate as the wood splints. In this way regularly-shaped heads are formed.

The paste heads will require some time to dry and harden, but the machine cannot afford to stand idle in the meantime; it must keep making matches all the time. There is nothing for it but that the machine holds on to the matches until they are dry, and so this long endless screen, in which the matches are fixed, moves along over one set of drums, and then winding around another series of drums, the matches have an hour's journey to and fro in the machine, at the end of which time they are dry and hard. The machine pushes the finished matches out of the perforations in the travelling screen. It places a definite quantity of these into the tray of an open match-box, and then gently closes the box and delivers it to a girl at the same end of the machine from which the wood splints set off on their long journey. Formerly this method of manufacture could be used only for making round wood matches, but it has now been adapted for the stronger square match.

The making of the boxes is also of great interest. Perhaps we have some recollections of trying to make paper or paste-board boxes in our schooldays; it took some time to fold the material neatly and paste the edges together. Here is a brainless automaton making one thousand boxes every minute; half a million boxes in a single day. It scores the strawboard for folding, pastes the edges, folds it to form the box-cover, prints it top and bottom, glues one side and blows sand on to it to make the striking surface, and then throws out the finished articles in a manner which reminds one of a quick-firing gun. The little trays are made for these by another ingenious machine.

The making of the little wooden boxes is of even greater interest. We are all familiar with the very thin sheet of wood forming the trays and cases of this class of match-box. First of all the round trunk of an aspen-tree is cut up into lengths of about two feet. One of these pieces is placed in a "peeling-machine," which rips or "peels" off a thin sheet of wood. The round tree-trunk is rotated while a sharp tool peels off a continuous sheet of very thin wood, or *veneer*. The machine at the same time scores the wood, making it ready for folding in the box-making machines.

These automatic box-makers take one of the prepared sheets of wood, push it forward to receive the pasted label, fold it, paste the edges, fasten the joint, wipe off the superfluous paste, and finally toss the finished box-cover into a basket, while other machines are busy making the trays to fit these.

Matches play an important part in the production of artificial light, giving a ready means of setting up combustion in larger masses of inflammable material, and their value to us in our everyday life cannot be overestimated. How helpless a man is in the dark if he cannot find a match to set a light to the gas, and how useless his cigar or his pipe if no one present possesses a match!

It is not so very long ago that people had to depend entirely upon the combustion of fatty substances to give them artificial light; in many country districts to-day we have candles and oil-lamps only. In front of some of the mansions in the West End of London there may be seen the receptacles into which the link-boys threw their flaming torches after escorting some wealthy citizens along the dark streets.

Attempts at lighting the streets were made as early as 1417, when it was ordained that "lanthorns with lights bee hanged out on the winter evenings, betwixt Hallow-

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MAKING GAS MANTLES

This photograph shows the last process in the manufacture. The finished mantles are being impregnated with collodion to make them less liable to breakage in packing and transportation. The collodion is burnt out before using the mantle for the first time.

tide and Candlemasse." This practice does not seem to have been kept in force, for we find that a similar command was issued about the end of the seventeenth century, which command set forth that the lights were to be kept burning "till the hour of twelve at night."

This Act must have been carried out in a very lax manner, for in 1716 we find the rulers still trying to enforce it by adding a penalty. This new Act states that houses fronting the streets must "in every dark night hang out one or more lights, with sufficient cotton wicks, that should continue to burn from six o'clock at night till eleven o'clock of the same night, under a penalty of one shilling." Even these regulations failed, because of bad management, and it was decided finally to give out contracts for the public lighting of the London streets with oil-lamps.

A great forward stride was taken with the introduction of coal-gas. Chemists had shown that when coal was distilled it gave off a gas which could be stored, and which, even after passing through water, remained inflammable.

In the closing years of the eighteenth century a Scotchman—William Murdoch—made numerous experiments in gas-lighting; he tried to purify the gas by passing it through water. It so happened that at this time he was appointed to a position of importance in the pioneer engine-works of James Watt, at Soho, near Manchester. Here he fitted up some simple means of producing coal-gas, with which he illuminated the works. This scheme was so successful that Murdoch extended his apparatus, and supplied all the principal shops in the neighbourhood with illumination.

Besides being superior in illuminating power, coal-gas was so convenient a method of lighting that people welcomed its advent. When, however, it was proposed to light the streets of London with coal-gas, great opposition was offered, James Watt himself declaring, along with Sir Humphry Davy, that there would be far too great a risk of explosion.

That London thoroughfare known as *Pall Mall* was illuminated by coal-gas in 1809, and four years later Westminster Bridge was lighted by the same means, the whole district of Westminster following suit. At the date of the late Queen Victoria's birth (1819) gas-lighting had become general in London and other large cities.

The general principle of the manufacture of coal-gas is very simple, and may be demonstrated in the following manner: If one fills the bowl of a clay pipe, such as is used by smokers, with small pieces of ordinary coal, it will be found an easy matter to distil the coal. Closing the bowl of the pipe with clay, and then applying the heat of a spirit-lamp beneath the bowl, will cause gas to be given off through the mouthpiece of the pipe. If a light is applied, after giving the heat sufficient time to drive out the air, a small jet of gas may be kept burning for some time.

At the gas-works several hundredweights of coal are placed in a closed retort, and raised to a high temperature by means of a furnace—just the clay-pipe experiment on a larger scale. There can be no combustion in the closed retort, as there is no air present to supply oxygen. The gaseous matter which is given off by the heated coal rises up a pipe and is discharged into a large main pipe. This gaseous matter contains a quantity of tar and ammonia vapour, which liquefy as soon as the temperature of the gas is lowered by means of a condenser. The tar and the ammoniacal liquor are run off into a well, and are valuable *by-products*. The gas is drawn along by an exhauster to a washing and scrubbing apparatus, where the ammonia vapour remaining in the gas is removed by bubbling the gas through water and by bringing the gas into contact with a large extent of surface kept wet by water. Even after all this purifying the coal-gas is not yet ready for our use. It has to pass through vessels charged with lime and oxide of iron, which have an affinity for carbonic-acid gas, and also for sulphuretted hydrogen, and when these have been left behind in the *purifiers*, the coal-gas is ready for sending underground to our homes, where it finds suitable exits on the walls of our rooms.

When the coal has been distilled in the manner described, there remains that coke or *gas-coke* which we use in furnaces.

It is fortunate that gas has a very pungent odour, a very small quantity present in the air being sufficient to stimulate our sensory organ of smell, whereas it requires several hundred times that quantity to produce an explosive mixture. If James Watt and Humphry Davy had observed this fact, they would not have offered the opposition to its use in the streets. I have seen, somewhere, an old cartoon depicting the streets of London lighted by coal-gas, and the pedestrians were holding their noses while they passed the lamps, some evidently overcome with severe fits of coughing, and so on.

Although the light produced by burning coal-gas was a great step in advance, it has been completely outdistanced by the incandescent gas-light, in which case the light is not produced by the burning gas, but by a solid body heated to a white heat by an almost invisible flame. The principle is the same as that of a limelight magic-lantern, in which case the combustion of oxygen and hydrogen gases produces only a very feeble light, but so much heat is evolved that the small block of lime becomes white hot, and this causes a very considerable disturbance in the surrounding æther, or, in other words, produces a brilliant light, which will illumine the whole lantern-sheet.

About twenty years ago an Austrian chemist — Auer von Welsbach—was making experiments to discover some substance which could be made white hot by the passage an electric current and yet be incombustible. While engaged in these experiments it occurred to Welsbach to use the heating power of coal-gas to maintain some incombustible substance at a white heat.

After a long series of experiments Welsbach found that some of the rare earths, previously known only in the chemical laboratory, would serve his purpose. He tried coating platinum wires with solutions of different rare earths, but he had to abandon this plan, as the latter soon collected in beads upon the wire.

He then tried soaking cotton in the solution, and then burning the cotton, he found a skeleton of the incombustible earths remaining. In order to get a good spread of illuminating surface, he used a knitted web of cotton to form a mantle, which he treated with a solution of nine parts of *thorium* and one part of *cerium*.

The method of manufacturing these incandescent mantles is of interest. After being soaked in the solution the mantle is dried on a glass rod and shaped on a mould. A loop of asbestos thread is passed around the top to provide a means of suspending the mantle. It is then placed in the centre of a hot flame which burns out all the cotton, leaving only a delicate skeleton of oxides, in which every twist and loop of the vanished thread is reproduced faithfully. In the illustration facing p. 228, an operator is seen carrying out this process of burning out the cotton.

After this the mantle is heated to a high temperature again, and after cooling it is dipped in a solution of collodion, and then dried. The collodion serves to strengthen the frail skeleton of the rare earths, and it is this collodion which we burn out after placing the mantle in position upon the gas-burner.

It has been observed already that the illumination in this case is not due to the light-giving properties of the gas, but to its heating properties. In the case of electric light the illumination is not due in any way to combustion. In the glow-lamps the electric current heats the filaments which are enclosed in vacuum, wherein combustion is impossible. In the open arc-lamp, some little combustion of the carbons does take place, but that is merely an effect of the high temperature, and in no way a cause of the brilliant light. But I pass over the subject of electric light, as I have already given a full discussion of this subject in another book of this same series—*The Romance of Modern Electricity*.

CHAPTER XVIII

MAKING SWEETS BY THE TON

THE title of this chapter conjures up visions of cartloads of sweets—enough to serve a whole army of children for a lifetime. I am taking no descriptive license in speaking of making sweets by the ton. It is not merely that a factory turns out tons of sweets in a day, but a single machine will produce as much as two tons of lozenges every day. If one could see the hundreds of tons of sweets which this one machine makes in a year, one could realize how it is possible for a modern factory to produce thousands of tons of sweets annually.

What a bewildering variety of bon-bons one finds in a confectioner's shop, and yet the chief ingredient of all these is sugar, so that a great deal must depend upon the way this substance is treated by the manufacturer.

If a schoolboy were asked what sugar is, he would probably say that it was a crystalline substance obtained by evaporating the juice of the sugar-cane or of beet-root. Or, if he were versed in chemistry, he might say that sugar was a congregation of atoms of these elementary substances—carbon, hydrogen, and oxygen—and he might suggest that sweets ought to be good for people, seeing these same elementary substances are three of the chief constituents of our own bodies.

The one kind of sweets which the amateur makes with varying success is toffee. Sometimes it turns out hard and glassy, while at other times it becomes all soft and sugary. The manufacturer's toffee always turns out right, for he understands the chemical changes which take place. In this particular department we find all the sweets which are made from boiled sugar, such as acid-drops, cinnamon-balls, and rocks. If one examines a round acid-drop, one can see that it has been made in a mould. But one finds that in the factory these are not made by pouring a liquid into moulds and allowing it to set. The boiled sugar is a flexible solid mass, and this is passed through between two metal rollers, each roller having a number of depressions which form half-moulds. As the material is passed through, these half-moulds come together and form the *drops* in the flexible mass.

The boiling of the sugar is of interest, for the manufacturer has enormous quantities to handle. He therefore adopts the most economical methods. We know that if we are on the top of a high mountain we can get water to boil at a lower temperature than it will when down on the plain beneath. The reason for this is evident; we have climbed up so far that the weight of the great blanket of air surrounding our planet is considerably less at that point, and this pressure being relieved, allows the water to boil with a smaller supply of heat energy.

MAKING SWEETS BY THE TON

He would be a very foolish manufacturer who would build his factory upon the top of a high mountain in order to save some coals in boiling his sugar, but he can produce the same conditions by artificial means. With a good air-pump he can relieve the atmospheric pressure in the boiling-pan to represent the condition which would prevail not only on the highest mountain, but right away up on the very outskirts of our atmospheric envelope. In these vacuum-pans the manufacturer only requires to produce a temperature of two hundred and forty degrees Fahrenheit, to get the same result that would require three hundred and twenty degrees without the vacuum. The necessary heat is conveyed to the sugar by means of a coiled steam-pipe placed within the vacuum-pan. The colour of the boiled sugar is also much better when treated in a vacuum.

Unless one has seen something of the manufacture of sweets, such as may be seen at many industrial exhibitions, one would not imagine that *rocks* were made of exactly the same material as toffee. The toffee is simply pulled out repeatedly till the air gets through among it, and when this hardens we have the well-known forms of rocks.

Another variety of sweets is in the form of hard white or coloured sugar. Sometimes this class is in the shape of hard balls like marbles, or they may have a hard white coat and an almond inside, and so on. These are made upon quite a different principle. The sugar is not boiled, as in toffee, but is melted into a syrup. Some of this liquid syrup is poured into a huge revolving pan, which is heated by means of a steam-jacket. When any objects are thrown into the syrup in one of these revolving pans, the objects will become covered with a fine coat of hard sugar. The heat drives out the water from the syrup, leaving the sugar adhering to the objects in a solid coat. By adding syrup as the heated pan revolves, the rolling objects are made to gather more sugar, and when they have attained the desired size they are removed from the pan.

If the objects placed in the revolving pan are almonds, then the resulting sweet is still in the form of an almond. If caraway seeds are used instead of almonds, then we have a sweet of the same shape as the seed, and so on. Some nucleus must be used to start the ball a-rolling, and the manufacturer speaks of this as the *bait*. Just as the angler in the stream requires a bait to catch the trout, so does the manufacturer require a bait to catch the sugar in these revolving pans. Some of these pan-made sweets may appear to have no special nucleus at the centre, but in such cases the manufacturer has probably used grains of sugar as the baits. After being taken out of the pans, some of these sweets are given a fine glossy polish by being placed in another revolving pan with some pure beeswax.

In the foregoing paragraphs we have seen how toffee sweets are made of boiled sugar and pan-made sweets of melted sugar. There is yet another method of dealing with the sugar, and producing that class of sweets known as *lozenges*. In this case the sugar is not melted, but it has to be very, very fine. A barrel, or bag, of ordinary crystallized sugar is emptied into a large box, from which it is lifted automatically by little buckets and poured into a mill, in which a disintegrator breaks the sugar up into a very fine dustlike flour. It is impossible for the machine to break every particle of sugar so fine as this, so it is necessary to pass the fine sugar through a sieve. But where can we find a sieve with meshes fine enough for the task?

When dealing with the manufacture of pottery, we found a fine metal sieve, having ten thousand meshes in each square inch, but in the present case even this sieve would be too coarse. The sugar sieve must have no less than twenty-five thousand holes to the inch, and the necessary material is found in a piece of very fine silk cloth.

After passing through the disintegrator, the sugar enters a large revolving reel, which is covered with this very fine silk fabric. The sugar which passes through the cloth is delivered by the machine in the form of a very fine flour, which is sent to the department where the lozenges are to be manufactured.

If the sugar is not to be melted, how will the fine particles stick together? Just by the same means as a postage-stamp sticks to a letter. The very fine sugar particles are mixed with pure gum-arabic, and are very thoroughly stirred or kneaded into a regular dough. This dough is placed in an ingenious machine which belongs to the same family as the biscuit-making machine, described in the succeeding chapter.

We shall suppose that the delicacies about to be made are those conversation lozenges upon which nonsensical little sentences are printed. The dough is fed forward in the form of a flat web, being rolled out to the required thickness. It is carried through the machine by a travelling band, which hands it over to a series of cutters; but on its way it has paused for a moment to receive the printed sentences from a type-bar supported over the web. When the web reaches the cutters, these sharp-edged shapes descend and cut through the dough in the same manner as the household cook cuts the dough for baking scones.

In the lozenge-machine, the dough which is cut remains in the shaped cutters, but, as these rise up again, a punch enters each cutter and pushes out the soft lozenge. It will not do for the punches to let the lozenges drop out on to the cutting-plate beneath. They must be removed clear of the machine at once, for the dough keeps stepping steadily forward, and the cutters must keep hard at work. In order to remove the lozenges without delay, a flat tray moves quickly forward, and pauses for a moment under the cutters, while the sweets are pushed out. The tray loses no time in getting out of the way, and it deposits the sweets in a large tray at the end of the machine, returning just in time to catch the next lot of lozenges as they are punched out of the cutters. This clever automaton can turn out two tons of lozenges in a day.

I think the most interesting machine in the whole factory is one which makes *gums*, or *jujubes*. These are cast in moulds, just as iron is, but the liquid material is

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A BESSEMER CONVERTER BLAZING

When crude iron is being converted into steel by the Bessemer process, the carbon contained in the iron ignites and great volumes of white flame pour forth from the converter.

poured in when cold, and the moulds, instead of being formed in sand, are impressed in fine starch powder.

When one watches the feeding end of one of these machines, it looks as if the object of the machine was merely to remove the finished jujubes from their moulds, for a girl keeps handing to the machine trays filled with these sweets in their moulds. These trays are not unlike bakers' wooden boards filled with fine starch powder, each tray having quite a crowd of little depressions in the starch, with a solid jujube in each of them.

The girl who is feeding the machine does not wait until the machine is ready for each tray; she keeps piling them up, one upon another, at the end of the machine. It is the duty of the machine to take away the bottom tray while the girl keeps adding trays to the pile. It is evident that before anyone could withdraw the bottom tray all the others would require to be lifted up. The machine is quite equal to this task. Whenever the machine is ready to take another tray under its charge, four little arms rise up, and, gripping the tray second from the bottom, lift the whole pile up while the machine draws away the bottom tray. The arms then lower the pile, let go the bottom one, and lift the remainder as before, leaving another tray free.

When each tray enters the machine, another arm tilts it over, throwing the jujubes and the starch powder out of it. The jujubes are shaken free of the starch powder, and, after being well brushed, they are handed out at the side of the machine, while the empty tray is refilled with starch powder and passed along through the machine.

The tray halts for a moment, while a regiment of little dies come down and imprints the moulds, in the starch, for a fresh lot of jujubes. A few more steps forward, and the tray halts again, while a regiment of little nozzles, corresponding with the positions of the moulds, squirt the liquid sweetstuff into the moulds, giving each the proper quantity required.

The machine, having completed its work, hands over the filled trays to a girl who is waiting to receive them. She builds up the trays in piles, and they are conveyed to a heated chamber near at hand. They remain in this room, or stove, for a week, and are exposed to a constant stream of hot air. By the end of the week the jujubes have become quite solid, and are ready to be removed from their moulds. The same machine which made them is given the full trays back again, and these are emptied by the machine as described already. And so the trays go round and round in a circular route, leaving the machine to enter a stove, in which they rest a week, then leaving the other end of the stove, to enter the machine once more.

The solid jujubes are usually *crystallized*, sugar-syrup being poured over them and allowed to drain off, the remaining coat forming into tiny crystals. This crystalline coat of sugar serves also to preserve the jujube.

The manufacture of chocolate-cream is too interesting to be passed over. The white "cream" for the inside is made in quite a strange manner. Sugar is melted in a large pan, from which it flows as a clear transparent syrup; indeed, as it passes through the air, in falling from the pan to a beating-machine beneath, it looks quite like a solid rod of dim glass. It passes through the beating-machine, in which it is subjected to a lively beating by propeller blades, revolving in opposite directions. When the material makes its exit from this machine, one would never recognize it as the same stuff which entered it. It has been transformed from the clear syrup into that solid and opaque white "cream," or fondant material, which is used for the inside of chocolate-cream. The transformation is remarkable, as no other substance has been added in the process of beating up. This machine can transform several tons of sugar-syrup into fondant material every day. This white "cream" is then moulded into bars, which are passed on to have their chocolate jackets fitted.

The manufacture of the chocolate is of special interest. Cocoa-beans arrive at the factory in their native state, having been brought across the sea from the West Indies, South America, and other distant lands. The beans are roasted in a large revolving stove like the cylinder of a coffee-roaster, but very much larger. The roasted beans are then passed through a winnowing-machine, which breaks up the beans and separates the light husks from the heavier kernels. These broken husks are used in some parts of the country for making a cheap tea, but the manufacturer does not place much value upon them.

The broken bits of the roasted kernels are called *cocoa-nibs.* When these are ground in a machine having heated metal rollers, the cocoa-nibs become liquid, which is practically very strong cocoa. This is passed through some other machinery which refines it, and at last it is mixed with sugar and ground on a granite bed by two large granite rollers which chase each other around the granite basin. This mixture of cocoa and sugar is *chocolate*, and as long as it is kept warm it remains in a liquid state.

In order to make the well-known cakes or bars of chocolate-cream, some liquid chocolate is poured into a metal mould; the bar of white moulded fondant fits exactly into this and acts as a core to the mould, while some more chocolate is poured over this to enclose the cream.

While some of the sweets already described require heat to solidify them, it is evident that chocolate must be an exception. Indeed, one can foresee that a chill would be more likely to solidify the chocolate, and one could quite imagine that a sudden transportation to the Arctic or Antarctic regions would be very effectual. The manufacturer brings the conditions of these Polar regions to bear upon the moulded chocolate by freezing it in a refrigerator.

In the great factories of John Buchanan and Bros., Ltd., of Glasgow, we find a fully equipped chemical laboratory, in which the expert analysts test all the materials before using them; there is no fear of any inferior or injurious substance being manufactured into the sweets.

The foregoing descriptions are intended to give only a very general idea of the processes of manufacture; the variety of bon-bons is endless, and novelties are being added continually. But among all the variety which

I saw being manufactured in the factories of John Buchanan and Bros., Ltd., there is one variety which I did not see. Indeed, I have seen it only once, and that was when passing along a back street in an old-fashioned town. My attention was attracted by a large tray of toffee in a very small shop-window. It was the apparent hugeness of the almonds embedded in the toffee which caused me to stop and look at it, but on closer inspection I found that the "almonds" were conversation lozenges firmly embedded higgledy-piggledy fashion in the toffee. My impression was that there was no need of applying for a patent for this novelty.

CHAPTER XIX

THE MECHANICAL BAKER

In the earlier chapters of this volume we considered how man had come to supply himself with the necessary materials for clothing. It is, of course, of greater importance that he should obtain food; but most of man's food is derived directly from Nature, and is not concerned with the subject of manufacture.

Bread, however, is a manufactured article. We give oats in its natural state to our horses, and the Scotchman boils oats with water to make porridge for himself, but when we make the flour of wheat into bread, we have something quite different.

The earliest method of making bread was to soak the grain in water, subject it to pressure, and then dry it. The next step in advance was to bruise the grain in a mortar or between two flat stones before moistening it. This was followed later by the grinding of the corn into flour.

When bread was made in the same manner as the household cook makes scones, by kneading flour and water, or flour and milk, together, and then firing, the resulting bread was called unleavened. The ordinary loaf bread is leavened, or, in other words, it has been subjected to a process of fermentation. We know that leavened bread is not a modern invention; it was common in the time of Moses, more than three thousand years ago. It was known that "a little leaven leaveneth the whole lump," but it is only within recent years that we have understood the reason of this. To-day we picture myriads of minute microbes at work in the mass, producing that condition which we describe as *fermentation*.

When we enter a bread factory, we find what I might describe as "the microbe department." Malted grain is steeping in large tubs of water. There are no employees about, but there are millions upon millions of little workers in these tubs, carrying on the process of fermentation.

I remember on one occasion remarking to a baker that he was very dependent upon the assistance of these microbes, whereupon he replied that they must be "healthy microbes," meaning that they were not hurtful. No microbes are hurtful unless they are in the wrong place; they are most helpful in their own spheres.

The chemical action set up in these tubs by the microbes is so great that the substance swells up, requiring four tubs to contain what was originally in one tub. Later on, however, the further chemical action brings the material back to about the same bulk as it possessed originally, when it is known as *barm*, or *yeast*. About four days are occupied by these little workers in bringing about the required change. It should be mentioned that the baker adds some old yeast to the malted grain and water in order to stimulate the action and produce the fermentation within the time required.

We are not to suppose that the work of the microbes is over when the yeast is formed. When certain proportions of flour, water, salt, and yeast are mixed together, the mixture is allowed to stand overnight, in order to give the microbes time to work a revolution in the contents of the tub. After that a vertical shaft, with blades upon it, is lowered into the tub, and the contents are stirred mechanically. Some flour is added at this point. The whole mass soon becomes of a spongy nature; indeed, the baker speaks of it as *the sponge*. Again the microbes are left in peace for about an hour and a half, during which time they work steadily on, altering the chemical arrangements in the mass.

The sponge is then handed over to another machine, in which two sets of long blades revolve, and turn the sponge over and over, interlocking air within the folds. The purpose of this *doughing-machine* is to aerate the bread while chemical actions proceed. There is a large quantity of carbonic acid gas given off, and it is this gas which expands or *raises* the mass of the dough. About a quarter of an hour's turmoil in this machine, and then the work is left again to the indefatigable microbes. If left indefinitely, they would soon play havoc with the dough, but when they have been at work for about an hour it is necessary to call a halt. Sentence of death is passed upon them as they enter the baker's oven, for they cannot live at so high a temperature, but they have some work to do before that final stage is reached.

The dough is placed in a machine, which very deftly cuts it up into lumps of the required mass to form a loaf. It cuts four "loaves" at each stroke, and these are very rapidly knocked into shape by the bakers, who place them in large wooden trays, buttering the ends of the loaves so that they will not stick together. At this point the microbes are given their last chance of action. These lumps of dough, moulded by hand, are placed near the great ovens. The gentle heat sets up further action, and carbonic acid gas is evolved in considerable quantities. This gas raises the dough to the required size. It is strange to watch the loaves growing during this "filling" stage. As soon as they have attained to their full stature they are placed in the oven.

Some of these ovens will hold over eight hundred loaves at one time. The baker uses a long rod, with a spade-like end, to place the loaves in the distant parts of the great oven. He uses this "peel" also when withdrawing the loaves from the oven. The name of this long shovel may seem strange, but it is derived from the Latin word for a spade.

About one and a half hours' lodgment in the oven, and the loaves are ready. Our willing workers, the microbes, have ceased to live. But I foresee a danger in vividly depicting the work of those microscopic bacteria. Some readers might run away with the idea that microbes are little insects endowed with some sort of instinct, whereas they are merely fungi, endowed with a simple form of vegetable life. They can only act when acted upon by their surroundings, and, as we have seen, when they are mixed with flour and water, they become very active agents, bringing about that condition of fermentation which is necessary for the making of ordinary bread.

There is another possible danger in depicting these microbes at work, but I trust it is a very improbable one. Some reader might come to think bread not so nice after reading this account of its manufacture, but that would be a complete mistake. These minute vegetable fungi are continually with us; they are in the food we eat, the air we breathe, and the clothes we wear. They are in our mouths and in our stomachs. It is only the disease germs that we have any cause of enmity against. They alone are hurtful parasites, and are in their wrong sphere, but even they are merely microscopic vegetable fungi.

Ordinary loaf-bread is made entirely of wheaten flour, of which there is a great variety. It is the baker's business to know how to blend the different varieties together, and in the loaf upon our breakfast table there may be flour grown in the United States, Great Britain, Austria, and Canada, all mixed together.

In the previous chapter we saw that when the confectioner desired his sugar flour to stick together in the form of lozenges, he had to add a sticky substance (gum arabic). The baker does not require to do so, because his wheat flour is rich in a very sticky substance called *gluten*, which gives the well-known tenacity to bread. When children desire to stick pictures into their albums, they ask the cook to make them some *paste*, and this she makes of flour and water.

The large ovens used in the mechanical baking of bread are heated by open coke fires placed in the corners at the fronts of the ovens. It is interesting to note that the modern oven is practically the same as the ancient ovens which have been discovered during the excavations of Pompeii, showing that there has been little change in this direction during the last two thousand years. There has been a new form of oven invented within recent years, but this is only suitable for the baking of *pan-bread*, which, as its name signifies, is baked in a closed pan. In this oven there is a large reel or paddle-wheel arrangement, which carries the pans round and round, bringing them in succession in front of a large fire. This *reel oven* is an American invention.

The advantage in the modern system of baking bread by machinery is not only that it is possible to produce tens of thousands of loaves per day from a single factory, but also that one can depend upon a uniform quality of bread.

Another branch of mechanical baking is the manufacture of biscuits, which is generally carried on quite apart from bread-making. In order to see a bread factory in full swing, in Scotland, one has to turn out of bed about three o'clock in the morning, as the shopkeepers demand a fresh supply of bread in the morning. But to see a biscuit factory at work, one need not be out of bed at "unreasonable hours." I am indebted to the firm of McVitie and Price for permission to watch the manufacture of biscuits in their London factories.

In biscuit-making there is no process of fermentation.

The ingredients are simply mixed in large tubs by propeller-like stirrers. This mixture is then kneaded by mechanical means, and the resulting dough is rolled out by a steel mangle to the required thickness. This forms a continuous web of dough, which passes along the biscuit-making machine, being carried forward on a travelling screen or endless band.

When the web of dough reaches the centre of the long machine, a regiment of cutters come down upon it and stamp out the biscuits, which fall on to travelling trays, while the waste dough collects at a higher level, and is removed, and rolled out once more to make up part of the new web of dough.

When the travelling trays reach the end of this long machine, they are lifted by boys and placed on another endless chain arrangement, which carries them into an oven. We have seen that bread requires to remain about one and a half hours in an oven, and, as the word "biscuit" is derived from words which mean "twice cooked," one might expect to find the biscuit being subjected to a longer lodgment in the oven. It is quite otherwise; the biscuits make a continuous march through a long oven measuring about forty feet in length, and the march through may not occupy as much as five minutes. When the biscuits make their exit at the end of the long oven, the trays are lifted by boys and placed in racks to cool, when they are ready for packing.

Each biscuit-making machine has its own oven, the machine and the oven being one continuous line of march, with only a space of a few feet between the end of the machine and the entrance to the oven. The rate of travel through the machine and the oven is the same in both cases. A single machine will turn out seven hundred thousand biscuits each day, or, if the smallest varieties of biscuits are being made, the output of a machine may reach the bewildering total of seven millions per day.

In the wafer-making department there are some interesting automatic machines. In one machine there is an endless chain of heavy iron moulding-boxes or "die-plates," which are flat, and which open like a book, the back of the mould being hinged. This machine is a hard worker; it goes at it all the time, and carries through every operation quite on its own account. It has a stock of the material from which the wafers are to be made, it has the trays for moulding the material, and it has a gas-heated furnace or oven.

As the moulding-boxes approach the top of the machine where they are to be filled, the machine opens the boxes, fills them while they continue moving, and then closes them. As these boxes are turned upside down during their return journey through the machine, each box must be securely locked. The machine requires no assistance; it undertakes the locking and unlocking itself, and it discharges the wafers after a hurried walk through the furnace. The whole time which elapses between the filling and emptying of the moulding-boxes does not exceed one minute. It only remains to pass these sheets of wafers through little machines having a number of circular saws, which cut the sheets of wafers into the well-known shapes.

THE MECHANICAL BAKER

When one is informed that a modern factory can produce about one hundred million biscuits per day, one cannot realize these unthinkable figures. This rate of production means that if the factory were ordered to produce a biscuit for every human being upon the face of the earth this very "tall" order would be executed in little more than a fortnight's time.

CHAPTER XX

CLOCKS AND WATCHES

ALMOST everyone possesses a timekeeper of some sort nowadays, and we are annoyed if we cannot tell the time to within a very few minutes of the common standard. It will be of interest to consider how we came to have clocks and watches. We shall see that these have been evolved from very simple ideas.

The ancients would, doubtless, observe the change of position of the shadows of rocks and trees, so that sun-dials were suggested at a very early date. As the sun did not shine always, other means of recording the passing hours were devised. The earliest idea was to let water escape in drops from a vessel, the falling level of the water in the vessel serving to indicate the time that had passed.

This idea reminds one of Richter's words:

"*Time is a continual overdropping of moments which fall down one upon the other, and evaporate.*"

And again the words of Baillie:

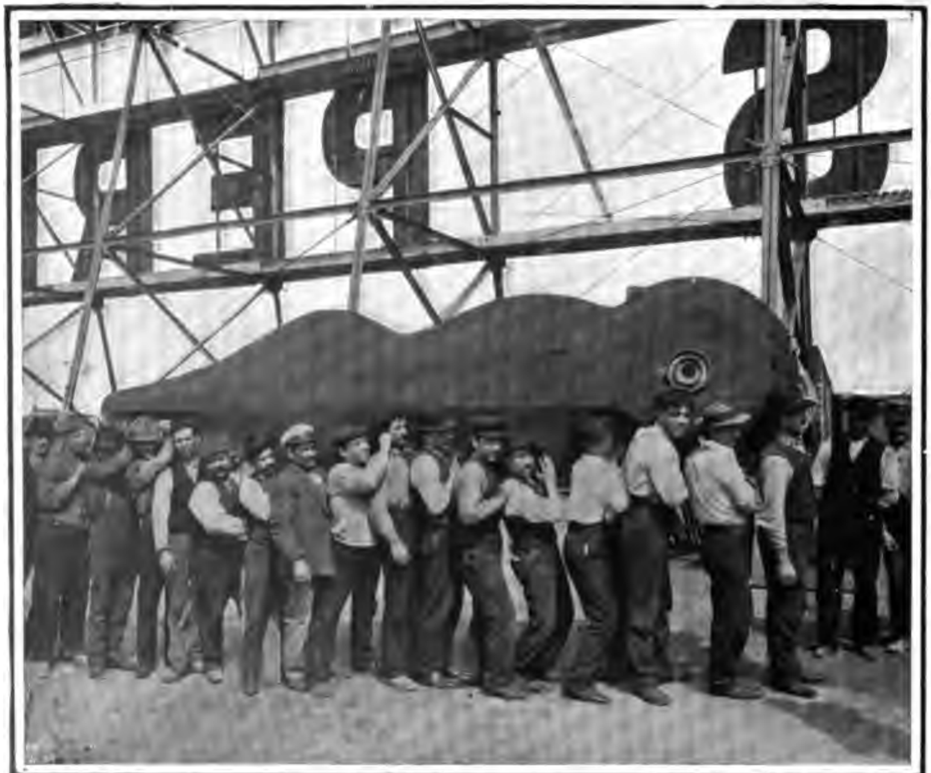
"*Each little moment at another's heels till hours, days, years, and ages are made up.*"

These water-clocks were called *clepsydras*, and they were adopted in many different forms by the Egyptians, the Greeks, and the Indians. In some cases the water dropped from one vessel into another, and a floating figure in the second vessel indicated the hours as the water rose. Sometimes the floating figure was in the form of a small boat with an outstretched oar to act as a pointer, the hours being marked upon the vessel. Here we see the origin of the hour hand of our clocks and watches.

Hour-glasses, in which sand passed from one vessel to another, were in use at the same time as these water-droppers, but it is the latter which interest us, as they are direct ancestors of the modern clock. Graduated candles were used at a later date, but these are not related to the invention of the mechanical timekeepers of the present day.

The Greeks introduced wheel-work in connection with these water-droppers, in order to move an indicator on a dial. While these mechanical clepsydras were of very ancient origin, they seem to have been re-invented, by some of the monks in France, about the close of the seventeenth century. One of these water-clocks consisted of a sort of water-wheel with small cells into which the water dropped. The wheel, which was driven round by the falling water, actuated suitable mechanism for striking the hours on a gong. These have gone out of use long, long ago, but one has been kept going in the Royal Observatory at Greenwich (London).

The falling water in these simple clepsydras had suggested the use of falling weights long before the monks took up the subject. We have a detailed account of a mechanical clock which was made for Charles V. of



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THE HOUR-HAND OF THE LARGEST CLOCK IN THE WORLD

In the above photograph sixteen men are seen carrying the enormous hour-hand of the largest clock ever made, some particulars of which are given in the text.

France about the middle of the fourteenth century. Although this pioneer clock was erected in France, the inventor was a German—Henry de Wyck. He used a heavy weight attached to the end of a rope, which was wound around a cylinder or barrel, so that as the weight fell the barrel revolved and gave motion to a train of wheels suitably geared to move an indicator or hour-hand. If the inventor had depended upon the falling weight to give him the rate of motion, his clock would have gone faster and faster as the weight gathered velocity in its fall. He had to devise a means of regulating the fall of the weight, and this he did by introducing a simple escapement arrangement in the train of wheels in the following manner:

An upright rod had two little spikes projecting from it, and these obstructed the motion of the last wheel in the train. The teeth of this wheel were on its side, and the spikes were so arranged that before the wheel could be turned by the falling weight the tooth resting against the spike, which was in an obstructing position, had to force the spike out of its way, whereupon the wheel was free to turn, but only to be held up again by the second spike. In this way the wheel could only turn one tooth at a time, and the rate of turning would depend upon the amount of resistance offered to the movement of the upright rod to which the spikes are attached. This rod had two arms upon which weights were hung, and by altering the position of these weights the obstruction to the movement of the mechanism could be increased or decreased as desired, so that a regulator was devised in this simple manner. Many copies of this original clock were made during the next three centuries, but none of these would be regarded as good time-keepers at the present day.

The next step of importance was the introduction of the pendulum. We all know that it was the great Galileo who was the first to observe the principle of the pendulum, but the story is always of interest. When this Italian philosopher was a lad of eighteen years of age, he was sitting one day in the Cathedral of Pisa when he observed the swinging motion of a hanging lamp. He was impressed with the seeming regularity of its swinging to and fro, and it occurred to him to test if the regularity of the swinging was as real as it appeared. Galileo was a medical student at this time, and when he compared the rhythmic movements of the lamp with the beat of his own pulse, he was satisfied that the swinging lamp made a constant number of vibrations in a given time. Galileo put this discovery to a practical test by applying a pendulum to a clock which was used for astronomical purposes. And so De Wyck's rod with the weighted arms was replaced by the pendulum, the movements of which controlled the escapement arrangement.

We shall not trouble with much detail, but it is of interest to note that these early clocks gave considerable trouble by going faster in cold weather than in warm weather. This was found to be due to the pendulum-rod expanding in warm weather; the longer pendulum would, of course, make a slower to-and-fro motion. This difficulty was got over in a very ingenious manner. Instead of using a simple weight as the bob of the pendulum, a jar of mercury was attached. The rise of temperature which caused the pendulum-rod to lengthen and tend to go slower also caused the mercury to expand or rise in the suspended jar, and this was equivalent to raising the weight upon the pendulum-rod, thus tending to make it go faster. Matters were so arranged that these two tendencies exactly balanced one another, and produced a perfectly compensating pendulum. This gave a very delicate compensation, which is still used in astronomical clocks, and in other very accurate time-keepers, at the present time. For ordinary purposes the mercury-jar has been replaced by a grid formed of metals having different rates of expansion, so that one expansion counterbalances the other. In the household clock we do not trouble about compensation.

With these compensating devices the clock-makers attained a degree of accuracy hitherto unknown, but we have evidence that they had not reached the ideal of the present day. When the order was given for the making of the great clock, "Big Ben," for the tower of the new Houses of Parliament in London, about the year 1840, it was stipulated that the clock should not vary more than one minute in a week. The *Clock-makers' Company* declared that this was quite impossible, but one clock-maker undertook the order and produced a clock which beat all the previous tower clocks for accuracy. The error of this clock was not as much as one second in a week. This degree of accuracy was remarkable, as the clock required a pendulum thirteen feet in length and a bob weighing six hundredweight.

When a desire arose for time-keepers which could be carried about by the owner, it was evident that the falling weight and the pendulum had to be abandoned. The falling weight was replaced by a coiled spring which in uncoiling itself gave the necessary impulse to the train of wheels. From our early experience in the nursery, we know that a clockwork toy will keep up a certain speed for a time and then gradually slacken pace as the spring becomes uncoiled. The early watches, or we might call them "portable clocks" because of their great size, had the same defect as our nursery toys. This difficulty had to disappear like its predecessors, and it was overcome in the following manner:

The driving power of the mainspring was bound to decrease as it unwound, so the only thing possible was to make the clock or watch more easy to drive as the force of the spring became weaker. This object is attained by making the mainspring act indirectly upon the mechanism by means of the following arrangement: As the mainspring uncoils it turns a barrel attached to it, and this barrel imparts motion to the mechanism by means of a small chain which is wound upon a grooved conical barrel, or "fusee." As the mainspring pulls the chain on to its barrel, the chain is drawn off this fusee so that it turns, and in turning moves the clock mechanism. When the mainspring is fully wound up, and its force upon the barrel is greatest, the chain is lying in the groove at the small end of the fusee, and therefore its leverage upon the fusee is least. As the force of the mainspring decreases, the chain is coming off a larger diameter of the fusee; hence a greater leverage is obtained which compensates for the loss of energy in the uncoiling spring. Every modern spring clock and watch which is a good time-keeper has a barrel and fusee arrangement as described.

In all watches and portable clocks a small balance-wheel takes the place of the pendulum. The to-and-fro swinging motion of this little balance-wheel was a thing of admiration to us in our childhood, when any possessor of a watch was willing to risk an exposure of the works. We used to watch this little wheel coiling and uncoiling the fine hair-spring, the throbbing motion of which is suggestive of heart-beats. As this little balance-wheel swings to and fro it allows the mainspring to unwind at a regular speed, just as the pendulum did.

Early in the eighteenth century Sir Isaac Newton pointed out the great advantage which would be obtained by mariners if they possessed perfect time-keepers on board their ships. The Government offered a fortune of twenty thousand pounds for a "perfect" time-keeper, but it was exactly half a century before this prize was won, in 1764.

One important feature in modern time-keeping methods is the increasing adoption of electric dials controlled by one clock. The master clock sends out an electric current at every half-minute, and this, on passing through a great number of different dials, moves the hands forward one half-minute. This means that only one clock has to be wound and regulated, the distant dials being merely indicators which move forward one step for each electric impulse received. It has always seemed to me a most unreasonable thing that in a large building such as an hotel there should be hundreds of little pieces of mechanism each trying to do the same thing, each requiring winding, regulating, and periodic cleaning. Very probably those who come after us will think we were foolish to continue so long with independent time-keepers, when one central clock can easily operate a very large number of dials over a wide area.

In the illustration facing p. 256, sixteen men are seen carrying the enormous hour hand of the largest clock in the world. This clock was built in 1908 for the Colgate factory in Jersey City (U.S.A.) A weight of eleven hundred pounds is required to drive the clock, while the hands weigh together more than half a ton. It is interesting to note that the great pendulum, which weighs in all about four hundred pounds, is kept going by an impulse imparted to it at the end of each stroke by a gravity arm falling against it and giving a slight touch of less than two ounces. This incredibly small pressure is ample to keep the great pendulum swinging. In an ordinary pendulum clock the very little force required to keep the pendulum in motion is got by making the back of each tooth in the escapement-wheel an inclined plane, so that the escapement-crutch in sliding over this receives a very small impulse, which it imparts to the pendulum.

Referring again to the largest clock in the world, it is difficult to realize its size. To say that its dial is nearly forty feet in diameter does not help one to realize the enormous size so well as the photograph of the hour hand already referred to.

CHAPTER XXI

THE MANUFACTURE OF IRON

NOWADAYS iron is the cheapest and commonest of all the metals, but it was not always so. Away far back in the world's history we find the ancients using gold, silver, copper, and bronze long before there is any mention of iron. The reason for this is not far to seek, for generation after generation of men might spend their lifetime in digging deep down into the earth, and yet they would never come across any iron. Iron does not exist as a metal in the earth; iron is only found locked up in combination with some other element.

In our schooldays we played with a curiously soft metal called sodium, which would catch fire and burn when thrown upon a damp surface. Sodium is never found in the earth as a metal, but it is found locked up in partnership with the element chlorine, and this compound substance we know as common salt, such as we use in our food. Sodium is so very closely united with other elements that its existence was not detected until the beginning of last century.

Iron is closely united with many elements, but it is not so difficult to extract as sodium. Indeed, we have substantial proof that iron was used in ancient Nineveh about three thousand years ago. The British Museum in London possesses iron picks, hammers, knives, and saws which were used in Nineveh so very long ago.

The early Briton had discovered means of extracting iron from its compounds before the arrival of the Romans, while travellers have found the natives of India and Africa using primitive furnaces for the extraction of iron.

Although the Romans carried on the manufacture of iron on a very large scale in Great Britain, as is witnessed by the great cinder-heaps in Yorkshire, their methods were very imperfect. The cinders of the ores, from which they believed they had extracted all the iron, have been used in modern times for the supply of iron. So much iron was found remaining in these cinders that they served as ore for twenty furnaces working constantly for several centuries.

In these early days, wood was the fuel for heating the iron-ore, and as the demand for iron increased, the forests of the country began to disappear, to the alarm of all concerned. There were dreadful prophesies of what would happen at no distant date when the timber was all used up, just as we hear alarming rumours to-day concerning the disappearance of coal.

I have mentioned in an earlier chapter that Lord Dudley took out a patent for the use of coal in smelting iron, which he produced much cheaper than his neighbours, but his ironworks were destroyed by the angry mob.

During the following century people became more alarmed than ever about the disappearance of timber, one writer declaring that there would not be left "so much in the whole country as will repair one of our churches if it should fall." In this way people were forced to adopt coals to obtain sufficient heat for extracting the iron metal from its compounds in the ores.

When iron has been extracted from the ore, the crude iron which is obtained is brittle, and cannot be beaten out by a hammer. In order to make the iron *malleable* (Latin, *malleo*, I beat), the crude iron has to undergo a further process in which the combustion of wood seemed to be an absolute necessity. It was only in 1785 that it was discovered that charcoal could be dispensed with, and malleable iron obtained by the flame of coal in what has been named a *puddling*-furnace. The inventor of this process was an ironmaster at Gosport—Henry Cort—who spent a fortune in working out his inventions. He also invented grooved rolls for rolling out the malleable iron into bars, dispensing with the tedious method of hammering. We shall see the marvellous development of this in the succeeding chapter.

Poor Henry Cort saw his fortune disappear in bringing his inventions to perfection, and so he was forced to take in a partner who could provide further capital. Adam Jellicoe, a deputy-paymaster in the Navy, was willing to supply the necessary money provided he was made a partner in the patent rights. Just when the inventions should have brought in the reward of Cort's labours, his partner was arrested for embezzling funds belonging to the Government, and as Jellicoe was a partner in

Cort's patents, these were taken over by the Government, leaving poor Cort penniless and broken-hearted. It is estimated that the value of these patents at that date was seven or eight times the sum required to cover the Government's loss.

Although Henry Cort reaped no material reward for his very valuable work, the iron industries of to-day are a great monument to his honour. Indeed, but for his inventions, Great Britain might never have reached her present important position in the engineering world. One statesman declared that the adoption of these processes was worth more to Great Britain than a dozen colonies. Our present methods of making the finished iron are merely developments of Henry Cort's inventions. Before dealing with these it will be of interest to see the modern method of extracting iron from the ore.

When the housemaid cannot get the fire to burn well, she causes a draught of air to pass through the fire. With the same idea the Romans built their iron-furnaces on the tops of hills, where they were sure of a good blow of wind. A good supply of air is necessary in the manufacture of iron, as oxygen plays an important part in the chemical changes which take place. A natural draught was used even in modern times, but about the middle of the eighteenth century one ironmaster fitted up a huge pair of bellows, which he worked by means of a water-wheel; then followed the general introduction of a forced blast.

In 1828, James B. Neilson, of Glasgow (Scotland), found that if the air was heated before being blown into the furnace the cost of production decreased, and so he took out a patent for the hot blast, which came into general use very quickly. The burning gases blazed out at the top of the high towers of the blast-furnaces, and the light which was reflected in the sky could be seen for miles around. I remember when the people of Glasgow used to speak of "Dixon's Blazes," which lit up the sky on the outskirts of the city. All these great blazes of light have disappeared now, for the loss of heat was so great that more economical means had to be devised. Nowadays the top of the blast-furnace is closed, and the hot gases are drawn off and utilized for heating purposes at the works.

When one visits any modern ironworks and looks at the regiment of boilers required to raise steam for driving the engines, one is impressed with two facts—everything is so clean and tidy, for there is no coal about the boiler-house, and the usual army of stokers, either manual or automatic, is absent. The blaze of white flame in the furnaces is due entirely to the burning of the waste gases drawn off at the top of the great blast-furnaces in which the iron is extracted from its ores. The steam in the boilers is kept up day and night, and the only fuel is these waste gases, so that this alone means an enormous saving in coal and labour.

The steam from these gas-heated boilers passes to the engine-house, where a very large and powerful engine is kept going day and night. This continuous task is divided between two similar engines, one resting while the other is at work, but going on duty before the other is called off, as there must be no pause in the continuous drive. When the blast-furnaces are once set agoing, they are kept hard at work without a moment's halt, year in and year out. The object of this incessant toil is not a matter of producing as much iron as possible, but the boilers which supply the power to work the blast are dependent upon the gases from the blast to heat them, and the hot blast is dependent upon this driving power, so the complete circuit must be kept up. When a blast-furnace has to be stopped for repair, it is a troublesome task and an expensive one to get it started again. The waste gases of the blast-furnaces are used also for heating the air, which is forced into the blast-furnace by the great engine.

So far we have seen a great expenditure of energy—the blast-furnace gases supplying the energy for heating the boilers, driving the engines, and thus producing the forced blast; but from whence does all this energy come? We know very well that energy cannot be created, but can only be transformed from one form to another. We find the source of energy in the fuel supplied to the blast-furnaces. These are not heated by gases; they produce the gases.

In order to see the blast-furnaces being stoked or "charged," we have to go to the very top of the high chimney or tower. We step into a cage very similar to that used in going down a coal-mine, but in the present case we go up instead of down. It seems quite a long journey to the top, although the gallery, on to which we step, is only about seventy feet from the ground.

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NIGHT SCENE AT A BLAST FURNACE

A very powerful electro-magnet is seen lifting a sow and pigs, just as they have been cast in the manner described in the text. Some of these magnets can lift 50,000 pounds.

The blast-furnace tapers towards the top, which we find is closed in by a large metal basin having the point of a metal cone projecting through a large hole in the centre of the basin. This metal cone is to act as a cork to the great furnace. The tapered end of the cone, which projects upwards through the hole in the basin, is kept drawn up by a heavy chain attached to a hand-winch, so that the furnace-top is closed completely. The charge of coal, iron-ore, and limestone is wheeled along the gallery from the cage-shaft to the top of the furnace. There it is tumbled into the large basin, and when a full charge is ready the cone is lowered for a moment, and then quickly raised again. The charge of materials falls down into the fiery furnace, while the gases blaze out during the moment that the top is open. The blast-furnace is fed in this manner continually through the day and night.

In the coal we see the chief source of energy, some heat being added by the other chemical changes which take place. The limestone is added to render the clay and other earthy matters in the ore and fuel more fusible. These earthy substances melt, and form what is known as *slag*. This slag floats on the top of the molten iron, and is drawn off from time to time as the charging of the furnace proceeds.

At last, when sufficient iron has collected, it is allowed to escape from the bottom of the furnace. The white-hot liquid metal flows along a channel, which is called the *sow*. This channel is formed in sand upon a gently-sloping piece of ground. Smaller channels, or branches, are formed, leading off the sow at right angles, and these short branches are termed *pigs*, the names being suggested by the idea of a sow suckling her numerous offspring. The molten iron flows into those pigs, and solidifies very quickly, the result being bars attached to a broader bar, as may be seen in the photograph facing p. 268.

The pigs may be detached from the sow while the mass is still red-hot, or the whole may be lifted by a powerful magnet, as shown in the photograph, and broken up while cold. The bars of pig-iron usually measure about four feet in length, and weigh about one hundredweight each, and if they have to be sent by rail or steamer the bars are usually left whole, while the sow is broken into short lengths.

It will be of interest to consider what takes place in a blast-furnace. We know that all compound substances are made up of atoms of a limited number of elementary substances. The compounds are not mixtures of the elements, but the atoms of the latter unite together in different forms, a particle, or *molecule*, of table-salt being composed of one atom of sodium united to one atom of chlorine. When we speak of a chemical change having taken place, we mean that there has been a re-arrangement of the atoms; different substances may take the place of the pre-existing ones.

When the substances placed in the blast-furnace are subjected to a very high temperature, the myriads of atoms get an opportunity of changing partners. In this connection I often think of a game which we played at children's parties. Each child selected the name of a town or place which he or she was to represent. All those playing the game sat in chairs around the room, except one child, for whom no seat was provided. When this child, who stood in the centre, spoke of a journey from London to Edinburgh, the two children who represented these towns had to change places, and during the change the child who had no chair tried to secure one of these two. At certain intervals a command, "general post," was given, whereupon every child had to vacate his or her chair and find another, and during this scramble it was an easy matter for the one in the centre to find a seat. Taking the child and the chair as partners, we have an analogy of what takes place in the blast-furnace at a very high temperature. There is a "general post"—a general exchange of atoms. The iron atoms and the oxygen atoms were partners in the iron-ore, but now they part company, the oxygen atom going into partnership with the carbon atom of the coal, and leaving the iron atoms very much to themselves. The carbon and oxygen atoms, when united, form carbonic oxide gas, and this is driven upwards through the materials farther up in the furnace, the gas carrying great heat with it. All the earthy matter in the ore and coal unites with the limestone and becomes molten slag, which, being lighter, floats on the top of the molten iron, and is run off at intervals, as already stated. This slag is a waste product. It is sometimes used as ballast in making a railway track, and in some special cases it is suitable for making bricks.

In the "general post" which we have been picturing some carbon atoms become attached to the molten iron, as also do some other elements contained in small quantities in the ore, such as phosphorus, silicon, sulphur, and manganese. The result is that the molten mass, when transformed into pig-iron, is by no means pure iron; i may contain from two to four per cent. of carbon, and smaller proportions of the other elements named. We shall see later how these ingredients are dealt with in producing the finished iron.

We have seen that the heated carbonic-oxide gas rises up through the materials in the furnace. Upon reaching the closed top of the furnace, the gas finds a way of escape by a large pipe, along which it is driven. The gas is partly robbed of its heat in imparting heat to a chamber through which the forced blast is passed on its way to the furnace. In other words, the hot blast is obtained from the heat of the waste gases, which are afterwards cooled and purified.

Various substances which are contained in a gaseous form in the waste gases are carefully extracted. The chief of these by-products is ammonia, and it is said to-day of many ironworks that their profit depends upon the amount of these by-products which they recover from the waste gases. The remaining gas (carbonic oxide) is led to the boiler furnaces, where it is utilized as fuel. This carbonic oxide gas must not be confused with "carbonic acid gas," which is carbon dioxide. The latter, as is well known, will not burn, and is a good extinguisher of fire, one of its vulgar names being *choke-damp*. The burning of carbonic oxide gas, on the other hand, is a familiar sight in ordinary fireplaces, producing the characteristic blue flames leaping up from the burning coals.

So far we have witnessed only the manufacture of pig-iron. This may be remelted at the foundry, and cast in moulds into different shapes, but it cannot be shaped by a hammer—in other words, it is not malleable, or wrought iron. In the succeeding chapter we shall consider the manufacture of finished iron and the making of steel rails.

CHAPTER XXII

MAKING STEEL RAILS

A NETWORK of steel rails is spread over the country connecting all the towns of importance together, while the streets of busy cities have long stretches of tramway rails laid along them. Vast quantities of steel girders are used in our modern buildings, while engineers and shipbuilders require enormous quantities of steel bars, plates, and angle irons. Indeed, the use of iron in such forms is so continually in evidence that it will be of general interest to see the methods of manufacture.

In the older methods of producing steel the pig-iron was melted on an open hearth, and in contact with the fuel (charcoal) it was exposed to a blast of air, so that the carbon in the pig-iron might unite with the oxygen of the air. The carbon and the earthy matter contained in the pig-iron were practically burned out of it, and a pasty mass of iron was left in the hearth. In order to let the air get at all the carbon in the iron, the contents of the hearth were stirred or mixed, and if the whole process was carried on long enough, there was only pure iron left. This pure iron was too soft for many purposes, so that the burning-out process was stopped before the decarbonizing was completed, leaving a small percentage of carbon in combination with the metal. The amount of carbon left determined the qualities of the metal.

If no carbon was extracted from the remelted mass, the result would be a brittle metal which we call *cast iron;* if the proportion of carbon left is less than one-fiftieth part, the resulting metal is called *steel*, but good steel may contain very much less carbon, while nearly pure iron is called *wrought iron*. Steel is intermediate to cast iron and wrought iron.

Henry Cort, of whom we read in the preceding chapter, proved that burning the iron in an open hearth with charcoal fuel was not necessary. He showed that the hearth might be heated from below with coal, and the mass well stirred as before. Since Cort's time this process of *puddling* has been greatly improved. If the pig-iron being puddled contains sulphur, then some manganese ore is thrown in to the molten mass to act as a "physic"; the sulphur leaves the iron to unite with the manganese, for which it has a strong affinity. Mechanical tools or stirrers have been introduced to make the process of puddling easier. After the carbon, or a large proportion of it, has been burnt out of the iron, there remains a pasty mass, which the operator rolls up into balls suitable for withdrawing from the furnace.

It occurred to Henry Bessemer, a Civil Engineer in England, that if he could cause air to be blown through the molten mass of pig-iron, instead of merely stirring the iron in the puddling-furnace, he would be able to get rid of the carbon in the iron more economically. When

Bessemer made his first experiments, he was alarmed somewhat at the phenomena which occurred. Melting some pig-iron, he had it poured into a large cylindrical vessel. At the foot of this vessel there were a number of holes or nozzles through which a blast of air was forced by a blowing engine. One might imagine that the liquid metal would flow into these holes, which were about half an inch in diameter, but the blast was turned on before the metal was poured in, and the force of the air issuing from the nozzles prevented the iron entering them.

The first surprise was that the temperature of the molten iron was greatly increased, although only cold air was forced through it. The chemical combinations which took place evolved great heat, and Bessemer was so impressed with this that he straightway read a paper to the British Association, entitling his paper "On the Manufacture of Iron and Steel without Fuel." Of course there really was fuel, but this was contained in the pig-iron itself, the carbon in the iron united with the oxygen of the air forced through the mass, and this chemical combination formed a true combustion.

Some alarm was felt at first, for at one point in the process a roaring flame rushed from the mouth of the vessel and produced quite a volcanic effect. Then beautifully coloured flames changed to a voluminous mass of white flame. This blazing of a Bessemer converter is seen in the illustration facing p. 240. It will be observed that the Bessemer converter is on trunions, so that it can be tipped over like a tea-kettle, and the converted steel allowed to flow into moulds to form steel ingots.

MAKING STEEL RAILS

Although Bessemer steel will not do for many purposes, and has been superseded largely by other methods, the value of Bessemer's invention has been demonstrated by the fact that one Bessemer rail lasted longer than twenty iron rails.

One drawback in connection with the Bessemer process was that the operators could not tell exactly at what point they should stop the process of decarbonization in order to leave the proper quantity of carbon in the metal. But Robert Mushet, whose name is well-known in connection with the making of steel, suggested a very simple way out of the difficulty. The metal was decarbonized completely, and then a quantity of good cast iron (*spiegeleisen*), containing the proper amount of carbon required and also a percentage of manganese, was added to the molten mass. In this way the amount of carbon in the finished steel could be determined with great accuracy.

In another process, which is interesting to see at work, the air is not blown through the mass, but flames of highly heated gas are made to play over the molten metal contained in a shallow hearth, the bed of which is formed of infusible sand. The heat of the waste gases is utilized to heat the perforated brickwork of the chambers through which the air and gas are passed. There are four of these brickwork chambers, and while the air and gas are passing through two chambers, the waste gases are passing out through the other chambers, and when these are sufficiently heated, the route of the air and gas is reversed so that they enter by these heated chambers, leaving by the others which have been cooled to some extent in heating the incoming air and gas and so on. This class of furnace is known as the Siemens-Martin regenerative furnace.

It is interesting to watch one of these furnaces at work on a dark night. The men have to keep throwing in lumps of iron-ore and occasionally limestone if the slag gets too thick. A man pulls the lever which raises one of the furnace doors, and, looking through blue spectacles, one sees a white-hot lake of molten metal. When the smelter throws in a large lump of iron-ore, there is a splash of "liquid gold." Indeed, to stand and watch these men throwing these heavy pieces in the furnace reminds one of the days when as boys we lifted large stones and flung them into a pond or lake, hurrying back to escape the splash of water.

After this real "inferno" has been at a white heat for several hours, the molten metal is run off into a huge ladle which rests on a railway trolley. This trolley carries the ladle to a row of heavy metal moulds, each standing over six feet in height, and looking not unlike so many overgrown cow-bells. The bell-mouth of each mould rests upon a metal floor, and when the metal is poured in at the top of the mould the molten mass becomes solid the moment it touches the cold iron base.

In less than an hour the bell-shaped mould is lifted up by a crane and the heavy steel ingot is left. These may weigh as much as ten tons each, but an average will be about three tons; these are stored till required.

When it is desired to convert one of these ingots into rails, girders, or angle irons, the ingot is placed in a furnace which is sunk in the ground. This furnace is

ROLLING OUT HUGE MASSES OF STEEL.

This really amounts to mangling a great red-hot ingot of steel, and rolling it into any desired form. The wonderful manner in which huge red-hot monsters are handled is told in Chapter XXII.

called a *soaking-pit*, the idea being that the heat must soak through and through the great mass of metal, and not produce a mere surface heat. After about an hour's lodgment in this subterranean furnace, the white-hot ingot is lifted out by an over-head crane, which carries it through the air to a *cogging-mill*. This mill might be described as a gigantic steel mangle with irregularly shaped rollers. The spaces between the rollers form large grooves of different dimensions.

When the crane lays the ingot on the ground, we are surprised to see this white-hot monster make a sudden rush towards the rollers of the mill, then, hesitating for a moment while the heavy rollers get a grip of it by the nose, the ingot passes through the widest groove, reappearing at the other side of the mangle somewhat longer and correspondingly smaller around its square waist.

The heat from this glowing mass of metal is intense, and although it weighs several tons, it is handled by this great iron giant as though it were a mere toy. Powerful steel fingers appear from the ground and turn the heavy mass over on its side, while two large arms gently place it opposite any desired groove in the great rollers.

The one-time ingot is passed and repassed through this great mangle, until the six-foot ingot is now about forty feet in length. It is now in the form of a heavy bar of regular shape, only its nose and tail being a little irregular, where it entered the cogging-mill in its journeys to and fro. The man in charge desires to cut off these irregular ends, and when he pulls a lever we see the long beam move forward and place its head below a powerful guillotine. A heavy arm descends and clamps the beam in position, while the beheading-knife cuts through the great mass of iron as though it offered but little resistance.

After cutting off the irregular end, the guillotine divides the long iron beam into two parts. One of these red-hot monsters leaves the guillotine, and goes scampering over the ground to a great distance. Watching it in the darkness, we see this fiery monster halt for a moment, swing round, and then go off in another direction. Just as the red-hot beam left the guillotine a very heavy gong was sounded to give warning along the route, for it would be fatal to be overtaken by this fiery serpent.

The method by which the great beam is propelled along the ground is interesting. Along the whole route there is a continuous series of rollers, placed across the path, only a few feet apart from one another, and sunk beneath the ground level, so that the tops of the circumferences of the rollers stand up a little above the ground. The beam lies on the tops of these "live-rollers" which are driven round by means of bevel-gearing on a long driving shaft at the side of the path.

It is an impressive sight to see the men in charge controlling all the movements of the great mass of iron, making it go through the mill, first in one direction and then in the other, turning it on this side and then on that. All the energy supplied by the men is to move the hand-levers, and these movements control the hydraulic machinery which handles the metal. Other levers serve to control the steam-engines which operate the mill and the live-rollers. The power required to drive one of the mills for rolling heavy girders in the works of *The Lanarkshire Steel Company* (Scotland) is obtained from a huge steam-engine of close upon ten thousand indicated horse-power, and this prime mover is so well balanced that it can race its crank round in one direction, stop very quickly, and then reverse.

When the second length of red-hot iron beam is about to leave the guillotine, we make our way along the side of the road it is going to take. The clanging of the great gong warns us of its approach, and as it rushes past we feel the intense heat radiating from it. By the time we overtake it again, we find that it is passing to and fro through another smaller rolling-mill.

First of all it goes through what is called a *roughing-mill*, which roughens the surface so that the rolling-mill with its specially grooved rollers may get a good grip ot it. In this mill the metal beam gradually assumes the shape of a rail, a girder, or an angle iron, according to the formation of the rollers between which it passes. As the metal beam passes to and fro through the rolling-mill, it goes through grooves of decreasing size, so that they reduce its section, at the same time increasing its length enormously. It so happens that the rolling-mill which we are watching at work is arranged for making bars of angle iron, which does not require so much metal per foot as a rail or a girder. By the time the rolling-mill has squeezed the red-hot iron into the finished angle iron, the twenty-foot heavy bar which arrived at this mill will measure about two hundred feet in length.

Indeed, there is not room for it to run back in a straight line along the live-rollers, as the road has a bend in it, so the end of the long red-hot bar runs up an inclined shoot towards the roof, and if necessary out through the roof. It is strange to see this great red-hot monster rushing up the shoot, and then sliding down again, as its distant end re-enters the rolling-mill.

As soon as the squeezing rollers have got to their closest position, the formation of the angle iron or the rail is complete. The accompanying diagram will give some idea of how the rollers squeeze a length of steel into the form of a rail.

It only remains to cut the long bar into suitable lengths. The bar runs forward and stops for a moment, while a large circular saw approaches it and cuts off the irregular end. The red-hot bar then moves forward any desired distance, and that length is cut off in similar fashion, and so on till the whole long length is divided up. When these circular saws are at work in the dark, they look exactly like the "Catherine-wheel" fireworks with which boys play, and which produce a fine circular display of sparks.

Only those who have some idea of the older methods of working iron can appreciate fully the enormous saving accomplished by modern machinery. In the old days the metal had to be handled in much smaller quantities, and it had to be lifted about from one operation to the next, requiring to be reheated between the processes.

We have seen that the six-foot ingot, after leaving the soaking-pit at a white heat, still remains red-hot when

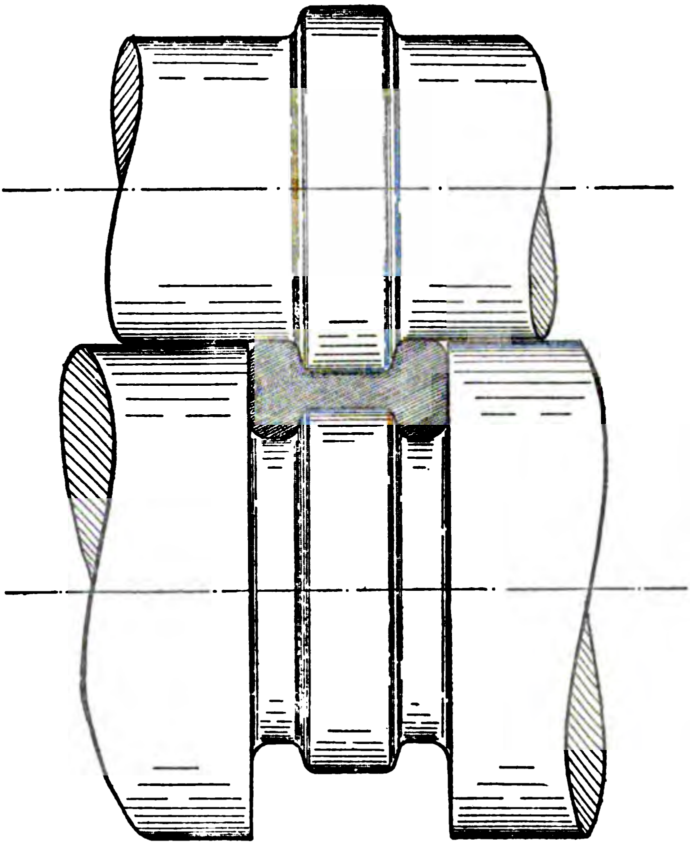


FIG. 15.—HOW A STEEL RAIL IS FORMED.

The rollers mangle the bar of steel to and fro, gradually closing the grooved rollers upon it until they reach their closest point. A section of the formed rail is represented by the dark shading; it is lying in the grooves formed by the two rollers.

rolled out to two hundred feet and cut up into the finished lengths. This is only accomplished by the mechanical means of handling the mass of iron. It rushes from one mill to another in a most businesslike fashion, and in about a quarter of an hour from the time the ingot leaves the soaking-pit it has been transformed into rails, girders, or angle iron.

In closing this brief description it may be mentioned that the quality of the steel is not arrived at in any haphazard fashion. Expert chemists analyze the materials from which the steel is to be made, and then determine the ingredients for the furnace. In many works even the structure of the finished metal is examined by means of very powerful microscopes.

CHAPTER XXIII

THE RAILWAY AND THE LOCOMOTIVE

THE ambition of many a boy has been that he might some day become an engine-driver. There have been other ambitions; I know of one little fellow who hoped he might be a coalman, the idea being that he might go about with a black face without the fear of his nurse chasing him around with a sponge and towel. Another little friend told me that if he grew up a gentleman he was going to be a clergyman, and if he grew up a workman he was going to be a carpenter. However, I believe that if a plebiscite had been taken of all the ambitions of the boys of a quarter of a century ago the engine-driver would have come out at the head of the poll.

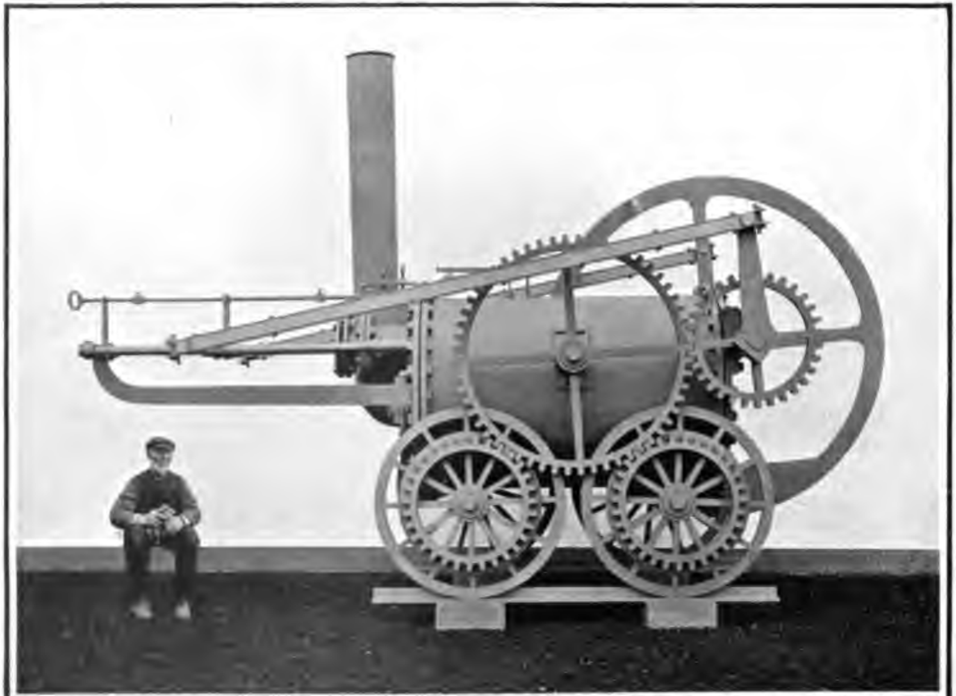
The suggestion of having a steam locomotive was a natural one after the success of Watt's steam-engine; indeed, Watt himself describes a steam locomotive in a patent which he took out in 1784, although he never put the idea into practice. Many people are under the impression that the idea of a steam locomotive originated in the mind of George Stephenson, whereas a practical steam locomotive ran on the streets of Paris before

Stephenson was born. It is true that this locomotive of Nicholas Cugnot (1769) attained only an average speed of two and a quarter miles per hour—about half the speed of a man walking at an ordinary pace—yet it was the first steam locomotive on record (see illustration facing p. 190).

The first idea was that locomotives should run on the ordinary roads, and there were many successful locomotives of this kind prior to Stephenson's time. In most of these cases the locomotive was a complete carriage, just as modern motor-cars are, but as early as 1803 the idea of having a separate locomotive to draw carriages after it was quite definite. I refer to a very curious-looking locomotive built by a clever but eccentric Englishman—Richard Trevithick (see illustration facing p. 286).

Trevithick's engine was successful in drawing waggons containing ten tons of iron at a rate of five miles per hour, but the inventor did not follow up his success. The best engineers of that time did not believe a locomotive could gain any great speed or climb a hill unless it were provided with a cogged wheel to work on a corresponding rack along the rails. We have a rack railway to-day, but that is to take a train up a mountain-side in Switzerland.

Trevithick's engine ran in South Wales when George Stephenson was twenty-two years of age, and this was twenty-three years before Stephenson's famous "Rocket" was built. Railways had been in existence for the purpose of taking trainloads of coal from the collieries to the shipping places for two hundred years, but horses had been used for drawing the waggons.



By permission of *London and North Western Railway*

ONE OF THE OLDEST

This engine was run successfully more than twenty years before George Stephenson's "Rocket." This earlier locomotive was invented by a somewhat eccentric engineer named Trevithick (1803).

RAILWAY AND LOCOMOTIVE

Railways had come about in a very natural way. About the year 1600 the colliery-owners laid down tracks consisting of a double line of wooden beams upon which the wheels of their carts might run. A horse which could draw only seventeen hundredweight of coal over the bad roads of those days was able to draw as much as forty-two hundredweight on the wooden rails. A flange was added to the rails to keep the wheels from slipping off, and permission was got from farmers to lay these wooden tracks across their fields, a rent, or "way-leave," being paid for this privilege.

People were content to work away with these wooden railways for one hundred years, but about the year 1700 long slips of iron were fastened to the wooden beams to prevent wear and tear. Some forty years later cast-iron rails, of the same form as the wooden ones, were brought into use. We often find these flat cast-iron rails in the neighbourhood of collieries at the present time.

It was the introduction of these cast-iron rails which suggested the use of crossbeams, or "sleepers," to give a proper foundation for the rails. And, finding that horses could draw such great loads upon these railways, the increase in the size of the waggon became so great that the idea of making smaller waggons and linking them together occurred to the colliery-owners.

These flat cast-iron rails would soon get filled up with stones and dirt, and so the next improvement was to put the flange upon the wheels instead of upon the rails, and this allowed the broad rail to be dispensed with, and the well-known edge-rail to be used in its place.

RAILWAY AND LOCOMOTIVE

Having traced the simple evolution of the railway, it will be of interest to see the advent of the steam locomotive. The eccentric Trevithick was the first to run a steam-engine on rails, but we have seen that nothing further was done for about twenty years. In the interim George Stephenson had constructed a primitive locomotive, which ran on a colliery line at a walking pace, which was no better than a horse could do. It could draw about thirty tons, but a number of horses could do this for about the same cost. In making a second locomotive, Stephenson hit upon a good idea; he turned the waste steam into the chimney, or funnel, in order to increase the draught. This proved a very great improvement; the fire burned so vigorously that the quantity of steam was greatly increased.

The next point of interest was the opening of the Stockton and Darlington Railway (thirty-seven miles), which was one of the first to carry passengers. Most of the passenger trains were drawn by horses, but steam locomotives were used for goods traffic. Then followed the Liverpool to Manchester Railway in 1830, which was originally intended for horse-haulage. George Stephenson was the engineer for the laying of this line, and he persuaded the directors to make an attempt with steam locomotives. They offered a prize of five hundred pounds if they could get an engine that would run at a rate of ten miles per hour and not weigh more than six tons. It is well known that George Stephenson's "Rocket" carried off the prize, and attained the alarming speed of twenty-nine miles per hour.

RAILWAY AND LOCOMOTIVE

It is difficult for us to realize the surprise of the people who saw the "Rocket" attain so great a speed. The most learned men of that time had declared that it was "palpably absurd and ridiculous" to suppose that locomotives could ever travel twice as fast as stage-coaches.

It is amusing to turn to the *Quarterly Review* of a few years prior to Stephenson's great achievement. In the issue of March, 1825, we find the following sentences: "It is true that we who in this age are accustomed to roll along our hard and even roads at the rate of eight or nine miles an hour can hardly imagine the inconveniences which beset our great-grandfathers when they had to undertake a journey, forcing their way through deep miry lanes, fording swollen rivers, obliged to halt for days together when the waters were out, and then crawling along at a pace of two or three miles an hour, in constant fear of being set fast in some deep quagmire, of being overturned, breaking down, or swept away by a sudden inundation. . . . As to those persons who speculate on making railways generally throughout the kingdom, we deem them and their visionary schemes unworthy of notice. . . . The gross exaggeration of the powers of the locomotive steam-engine may delude for a time, but must end in the mortification of those concerned. . . . We should as soon expect the people of Woolwich to suffer themselves to be fired off upon one of Congreve's ricochet rockets as trust themselves to the mercy of such a machine, going at such a rate [eighteen miles per hour]. . . . We trust that Parliament will, in all railways it may sanction, limit the speed to eight or nine miles per hour, which is as great as can be ventured on with safety."

We can imagine what the writer of the foregoing article would have said had anyone dared to prophesy a speed of sixty miles per hour, with an occasional short dash of ninety miles per hour. We know that electric trains have beaten these records of the steam-engine, a maximum or one hundred and thirty miles per hour having been attained.

From the illustrations facing pp. 286 and 296 it is apparent that the early locomotives were mere toys compared with our modern express engines. The making of railway locomotives is now a great industry. We find thousands of men employed in individual works, all busy making and fitting up these great iron horses.

Of course the starting-point is in the brain of the designer; he has to build the engine in imagination, and after he has made his drawings he can test the working of the moving parts by means of a large model fixed to the wall of the designing-room. He can lengthen or shorten the crank and levers in this large model to agree with his drawing, and by watching the valves when the crank is rotated he can satisfy himself that everything works out as he expected. He then sends his drawing down to the tracing-room, where a large number of young ladies are employed making careful tracings of the original drawings. These tracings are not to be handed out to the workmen, but are to be used as negatives for obtaining photographic blue-prints.

The old plan of making these prints was to place a piece of sensitized paper under the tracing and expose it to sunlight, just as one does in printing an ordinary photograph. The paper used has been prepared with ferro-cyanide, which, when exposed to light, becomes blue, except upon those parts which have been protected by the lines on the tracing. This process of daylight printing often proved very inconvenient. It was slow, and then one could not get the sun to shine when required.

The present method of copying these tracings is to have a large upright cylinder, within which there is a powerful electric arc-lamp, which travels automatically up and down the cylinder continuously, while the tracing with the sensitized paper beneath it makes a journey around the cylinder, entering at one side and coming out at the other. The whole printing will take about one minute, whereas with the older method one had to wait at times, somewhat impatiently, for half an hour till the fickle sunlight would do the same work.

These blue-prints then go to men who prepare the work. Some prints will go to the pattern-makers, who will construct the wooden patterns to enable the moulders to form the sand moulds in which the iron and brass are to be cast. Other blue-prints will go to the shop in which the *templates* are made.

When a young lady is desirous of making for herself a fancy blouse, she buys a paper pattern showing the shapes of the different parts required. She places these paper patterns upon a piece of cloth and cuts around the shapes. The engineer works upon a similar plan for cutting out and shaping many parts of his engines; instead of making his patterns, or *templates*, of paper, he makes them of substantial sheet-iron. These are marked off carefully, indicating where holes are to be drilled, and so on. The template for the frame of a locomotive is an immense thing, being, of course, an exact pattern of what the actual part is to be.

We need hardly enter the foundry, for the general principle has been explained already in connection with the making of sewing-machines, but in the locomotive works the castings are on a very much larger scale. The casting of the large cylinders for an express locomotive is no light undertaking.

The same remarks apply to the forge, but it is of interest to see how the larger pieces of iron and steel are handled. When we see a huge bar of iron, of about a one-foot-square section, being withdrawn from a furnace to be hammered into a definite shape, we picture the village blacksmith trying to tackle this job. The energy that a man would have to expend would be enormous; indeed, he could not hope to make much impression on so large a mass of metal. Compare this with the duties of one of the boys who operate the powerful steam-hammers at work in this forge. It has seemed to me a very curious fact that almost every boy, while at this work, sits with his legs crossed and one hand in his pocket, as though this attitude had been arranged by way of contrast, while with his other hand he moves a light lever up and down, each motion being imitated by the great steam-hammer, whose powerful blows soon shape the mass of metal into any desired form. Or it will weld one shaped piece to another, and so on.

A steam-hammer is simply a strong piston working up and down in a steam cylinder, the inlet of steam being controlled by the boy already referred to. The free end of the piston forms the hammer-head. This powerful tool, as we know it to-day, was invented by Nasmyth, of Manchester, in 1839.

Another hard-working tool is the hydraulic forge, or press, such as shown in the illustration facing p. 216. Some hydraulic presses are made to exert a pressure of thirty thousand tons, though the locomotive builder will probably find one of twelve to fifteen hundred tons pressure sufficient for his heaviest work.

The hydraulic press, as its name implies, does not deal out sharp blows like the steam-hammer, but exerts a slow pressure, bending great plates of iron into the forms desired. A flat circular plate of iron is heated and pressed by a mould into the well-known form of the dome upon the top of a locomotive boiler.

It may happen that some special shape has to be formed for which the engineers possess no mould. Suppose it is a certain size of plate to be bent up at right angles around the four sides. In this special case a number of smiths attack the heated plate with heavy wooden mallets, which will not mark the metal, but by the time four smiths have finished one piece, the hydraulic press, if it had the proper mould, would have accumulated quite a pile of similarly finished parts.

In constructing the boilers a large number of rivets are required, so the making of these is undertaken by an automaton, which does not feel the monotony of always doing the one thing. Long bars of round metal of the dimensions required for the shank of the rivets are heated in furnaces and then placed in the rivet-making machine; the bar keeps putting its head under a guillotine, which cuts off the required length. These short pieces, while still red-hot, are placed in a revolving carrier, which whisks the rivet under a small steam-hammer, and with one smart blow this hammer forms the well-known rivet-head.

Much more wonderful are the machines which make screwed bolts and similar things. These machines are perfectly automatic, one man acting master to as many as five machines. He merely hands them each a long bar of steel, and watches that they do their work satisfactorily. He gives one machine a long hexagonal bar, which the machine undertakes to convert into special bolts. These are to have hexagonal heads, plain round necks, and they are to be screwed along the remaining three-fourths of their length. The machines are really automaton lathes.

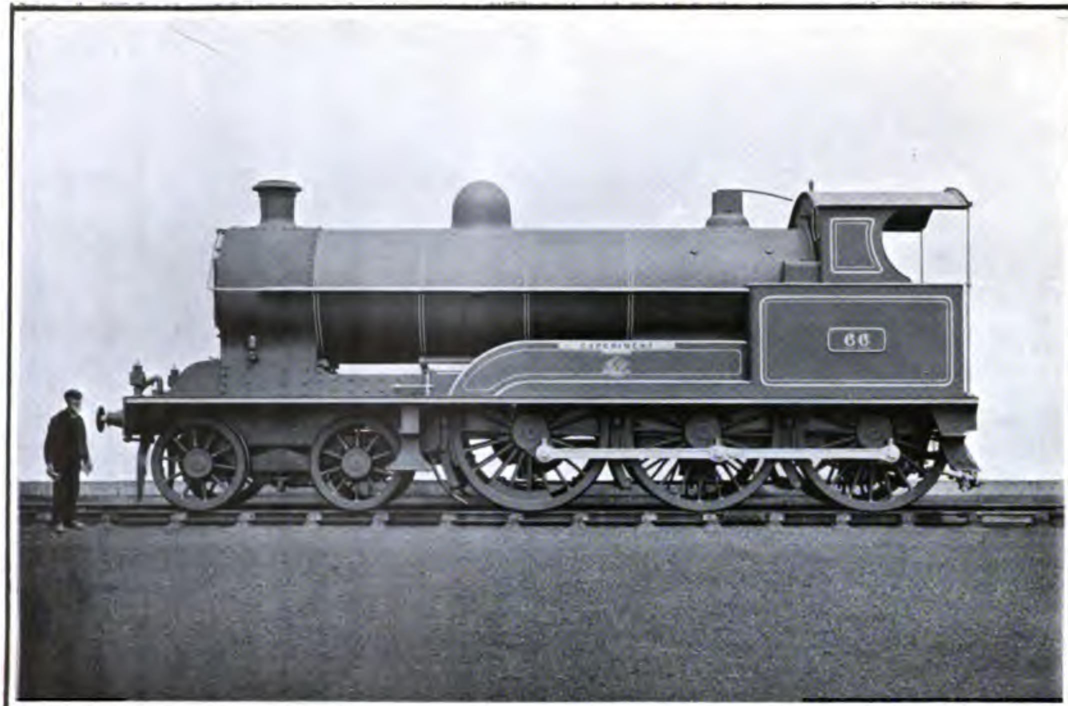
When the machine feeds in the long bar, a finger comes forward from the opposite direction and pushes the bar back till exactly the correct length is exposed from the feed. One tool then cuts away the hexagonal circumference of the bar, making it nice and round, and leaving only sufficient of it hexagonal to serve as a head for the bolt. Then another tool cuts into the bar just beyond the head, but at this stage it refrains from cutting it quite free. Another tool comes into action and puts the desired screw-thread upon the bolt, and, as soon as this has been completed, the cutting tool again approaches the head and severs the bolt from the long bar. The machine then feeds in another few inches of the hexagonal bar, and proceeds to make another similar bolt. Other automata are busy making those shapely studs which support the hand-rail along the side of the locomotive, and so on. It is quite strange to see a large number of such machines, each working away at its own job, changing its tools as required, completing one article and then commencing another, doing all this on their own account, while their master—the workman—is engaged attending to something else.

The amateur carpenter very soon learns to plane and saw wood, but if he desires to work upon pieces of iron instead of wood he finds that he must exert a great amount of energy. The practical engineer does not worry about the energy required to plane or saw large pieces of iron; he simply hands the work over to a machine to do all the necessary hard work. In one class of planing-machine a travelling carriage, or platform, carries metal to and fro under a fixed plane, while in others the work is stationary, and the planing tool travels to and fro. I mention these facts, as one sees those planing-machines so often at our industrial exhibitions.

When these machines have a revolving cutter not unlike a garden-mower, but solid, they are called *milling-machines.* Then there are different kinds of drilling-machines, but these have been referred to in the chapter on *Sewing-Machines.*

Each mechanic receives his work all marked off, so that he can place it in the machine in its proper position to be drilled, planed, slotted, or whatever else is required to be done. Each workman does some little towards the completion of the great locomotive. One lot of men have been making the parts required for the cylinders, and when these have been fitted together the complete cylinder has to undergo a series of severe tests. First of all it is filled with water under great pressure, and then it is tested with steam, and when quite satisfactory it is handed over to the *erecting-shop*. Other men have been busy making the different parts of the boiler, and these are dealt with in similar fashion.

The making of the wheels has employed other gangs of men. The wheels are made of cast steel, and as the rims are to be subjected to very great friction, it is necessary to have them as hard and tough as possible. Just as the wooden cart-wheel has a metal tyre put around it, so the steel wheel of the locomotive is also tyred. The tyres for the locomotive are made of special steel, and they are put on in the same way as the blacksmith adopts in dealing with the cart-wheel. In the case of the locomotive the heavy steel tyre is laid upon the ground with a circle of gas-jets playing upon the metal circumference. When the tyre has expanded sufficiently, the wheel is placed within it, and the heat is withdrawn, whereupon the tyre contracts gradually and takes a great grip of the wheel. It is afterwards fastened further with metal bolts. When the wheel becomes worn, it is sent to the repairing-shop to have a new tyre put upon it.



By permission of *London and North Western Railway*

ONE OF THE LATEST

This is one of the modern express locomotives of the "Experiment" class. It is interesting to compare this with the illustration preceding this one. The same man appears in both pictures.

In the erecting-shop there is necessarily a great deal of manual labour, although even here many automatic tools, driven by compressed air or by electric-power, are brought into play (see illustration facing p. 130).

Needless to say, the building of a modern railway locomotive is carried out on scientific principles. The different parts are each made of the particular quality of iron or steel best suited for the purposes the parts have to serve. It is surprising how a very small variation in the composition of the iron may alter entirely its distinctive properties. The means of producing different qualities of iron and steel have been dealt with in the chapter on *The Manufacture of Iron*.

It is a curious thought that these great express engines which race across the country with us are composed of little invisible molecules of iron, and that the stability of the whole frame and of the going parts depends entirely upon the natural clinging of these molecules to one another.

In the moulding-shop the intense heat of the furnace sets these little molecules vibrating at such a rate that they could no longer hold on to one another. The moulder seized this opportunity of placing them in a mould of the shape he wished them to remain when they once got into grips with one another again. In the forge the same method was used, but as the molecules were not freed sufficiently to lose all grip upon one another, some energy had to be expended to force the molecules into new positions; hence the use of steam-hammers and hydraulic presses. As we fly across the country in our fast express trains we are trusting our lives to those ultra-microscopic molecules, each doing its duty and holding firmly on to its neighbours.

Needless to say, each locomotive is severely tested before it leaves the builder's hands. The locomotive is first of all placed so that its driving-wheels do not touch the rails, but rest upon the circumferences of other wheels. In this position all the going parts of the engine may be tested while the locomotive remains stationary. It can be made to record its speed and its tractive power. Then when all is considered satisfactory, the locomotive is allowed to go on its own wheels, and after being tested upon short tracks in the builder's yards, the locomotive is sent out on to the public railway, or if it is to go abroad it is taken to pieces and packed in cases.

CHAPTER XXIV

BUILDING A SHIP

We all know that ships are not modern inventions; they have been going about on the surface of the seas of this planet for thousands of years.

The evolution of the ship from floating-rafts and from canoes cut out of solid wood was quite natural.

Not content with depending upon the fickle wind, the ancients propelled their ships with oars. Doubtless we have all had vivid imaginings of the galley-slaves of Rome, chained to their seats while they rowed long galley-boats or ships on the Mediterranean Sea.

The next forward step was made by the Romans introducing paddle-wheels in place of oars. These paddles were sometimes driven round by men, but oxen and horses were employed also. This form of paddle-ship was renewed in modern times for ferry-boats. A Scotchman, Miller by name, made many experiments with paddle-ships of this kind, but he found that the men were very easily exhausted, while the use of animals was not very convenient. It occurred to him that the then recently invented steam-engine of James Watt might be made to drive the paddles round.

It so happened that about this time (1786), Miller heard of a model steam-carriage being exhibited in Edinburgh by James Symington, a mining engineer. Miller found that Symington was of opinion that the steam-engine which he was exhibiting would be quite as suitable for turning the paddle-wheels of a ship as the ordinary wheels of a carriage. Of course it seems ridiculous to us that anyone could doubt such a simple fact, but we must remember that we have grown up among these inventions.

Symington agreed to build an engine for Miller, and by the end of 1788 all was ready for the trial trip on an inland lock. It is interesting to note that the great bard of Scotland, Robert Burns, was one of the five passengers on board this first steamship on her maiden voyage across the little loch. But even Burns's clear mind did not foresee the importance of the event; he has left no verse concerning it. Personally, I think this shows Burns's wisdom; the whole affair was so novel that he would not wish to express what might remain a permanent opinion concerning its future. In the preceding chapter we saw how foolish the early critics of the steam locomotive appear to us now.

Symington made further experiments with a larger boat on the Forth and Clyde Canal, which crosses Scotland from east to west. This larger boat attained a speed of seven miles an hour, but it was so lightly built that it could not stand many trips. Miller was supplying the funds for these experiments, and finding this a heavy drain upon his purse he abandoned it.

Symington was an enthusiast, and he got a Scottish

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A MAGNETIC PILLAR

When using an automatic drilling machine it is necessary to fix the machine firmly in position. The above illustration shows a very convenient method of clamping the tool to a heavy iron plate, such as the side of a ship. The base of the pillar is an electro-magnet, and it is evident that it is more than equal to its task, for in addition to holding the tool it is supporting the three men who are standing upon it.

nobleman to provide three thousand pounds for the building of a stronger ship to be used on the canal as a steam-tug. This boat proved a success, but at its trial trip it was declared that its wash would injure the whole banks of the canal, and so the vessel did not come into use as a tug.

There is something pathetic about Symington having to abandon his great scheme after he had proved that his ship could steam against a strong wind, against which no other vessel could make headway, and at the same time pulling along two vessels of seventy tons each. If Symington had suggested that they should strengthen the banks of the canal to suit his steamer, he would have been laughed out of court. Indeed, it would have seemed to them just as ridiculous as the little boy asking the keeper at the Zoological Gardens if a currant out of his bun would hurt the elephant.

When our old clerical friend, Dr. Cartwright, lost his fortune in his heroic efforts to establish weaving by machinery, he went to London to earn a living by his pen. Even then he was always busy with some ideas concerning mechanical affairs. He used to discuss the problem of steam-navigation with a young American artist, Robert Fulton, who was a constant visitor at the doctor's London house.

The ingenious clergyman made a model of a paddle-steamer, which was driven by means of clockwork, and which he gave as a toy to a little fellow who became afterwards the great statesman, Lord John Russell. No experiments were attempted with steam, but Fulton was keenly interested in the subject of steamships, of the future of which both he and Dr. Cartwright were enthusiastic.

Some years later, when Fulton was on a visit to Scotland, he got an introduction to Symington, who was most generous in giving full particulars of his ship, and in giving Fulton a trip on board his boat on the canal. It should be mentioned that Fulton told Symington quite frankly that he intended building a steamship as soon as he returned to America.

Fulton's American friends laughed at his scheme, and spoke of it as "Fulton's Folly." No one would risk a penny in such a ridiculous undertaking. Although Fulton received no encouragement from anyone, he plodded along, and, having got his vessel launched, he proved that he was no madman.

We have grown up among steamships, so that it is difficult to realize the great surprise of those who witnessed this new invention. Fulton's biographer tells us that when the steamer came along the River Hudson at night, breathing out flames and smoke, and defying the winds and the tide, the crews of the sailing-ships were so alarmed at the approach of this monster that some of them took to their small boats and pulled for the shore, while others fell upon the decks and prayed for protection against the approach of the horrible monster. The flames would be rather alarming, as the fuel was pinewood, which, when stirred by the stoker, would send forth great showers of flaming sparks. Then the unusual throb of the paddles coming through the darkness would seem uncanny.

Fulton's pioneer steamer, *Clermont*, became a regular passenger steamer between Albany and New York, and other steamers soon followed.

It is interesting to consider what happened in Great Britain after Symington was forced to abandon his scheme. A Glasgow carpenter—Henry Bell—had been keenly interested in the subject of ship propulsion, and it happened that Bell accompanied the young American artist, Robert Fulton, on his visit to Symington in Edinburgh. Bell and Fulton kept up a correspondence, but it occurred to Bell that instead of passing on all his opinions to America, he ought to make a practical experiment in his own country.

About this time Bell became proprietor of an inn at Helensburgh, on the banks of the River Clyde. While there he made some experiments with paddle-boats driven by hand, and then sought to introduce a steam-engine to turn the paddles. His mad scheme became a standing joke on the Clyde, but Bell also was an enthusiast.

When Bell had succeeded with a small boat of twenty-five tons and four horse-power, he placed it on the Clyde to carry passengers between Glasgow and Helensburgh, a distance of about twenty miles. But the canny Scots were very slow to trust themselves in Bell's steamer, the *Comet*.*

* Henry Bell's *Comet* was built in Scotland about five years after Fulton's *Clermont* in America, and about twenty-three years after Symington's first steamer referred to in the text.

The late Lord Kelvin used to tell how his father and a party of fellow-students, after landing at Greenock from Ireland, were walking to Glasgow to attend the opening of the University session (1813), when "on their way they saw a prodigy—a black chimney —moving rapidly beyond a field on the left-hand side of their road.

The owners of stage-coaches and sailing-vessels spread evil reports about the *Comet*, but when it had run without accident for some time, the tourists began to patronize it, and Bell was encouraged to try his vessel in the open sea around the coast. Unfortunately the little vessel was not strong enough for this, and was wrecked. A second vessel was burned, leaving Bell in money difficulties. By this time rivals were building steamers, and against these capitalists poor Bell had no chance, so that he sank into poverty. Subscriptions were raised among friends, and with a small annuity from the Clyde trustees Bell was kept from starving, but to-day the great shipping enterprises on the Clyde stand as a monument to Bell's pioneer work.

The general principle of shipbuilding has not altered much since the days of the Roman galleys rowed by slaves. These ships had wooden ribs to which the wooden shell was fixed, while the seats for the rowers acted as cross-beams to strengthen the ship.

People were content with wooden ships until the invention of heavy guns, whereupon the French Government protected some of their wooden warships with a covering or coat of iron plates. Then the struggle began between the gunmakers and the shipbuilders. The former made guns which could pierce the iron plating; then the shipbuilders put on heavier iron plates, and so on they went. At first the ships always had a wooden lining to

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They jumped the fence, ran across the field, and saw, to their astonishment, Henry Bell's *Comet* (then not a year old) travelling on the Clyde between Greenock and Glasgow."

the iron, and in some cases an inner lining of iron also. When ships built entirely of iron were tried in 1836, they came into general use very quickly.

One might think that an iron ship would weigh a great deal more than a wooden ship of the same size, but as a matter of fact an iron ship is much lighter, for the required strength is obtained with very much thinner walls.

It will be of interest to see how the modern shipbuilder sets to work, and we shall suppose that he is going to build one of those gigantic "liners," or a warship such as is shown entering the water in the illustration facing p. 310.

The preparatory work of drawing and making blue-prints from the tracings is very much the same as has been described in the preceding chapter on *Locomotives*. But there is one important difference in carrying the design into operation. The locomotive-builder made a full-sized template of the whole frame of his locomotive, but it goes without saying that the shipbuilder is not going to make a full-sized template of his ship. Leaving the size out of account altogether, it must be apparent that the conditions are entirely different. The side of a ship is not a piece of flat metal; it bulges out from the keel to the deck, and from the bow to the stern. We speak of the beautiful *lines* of a modern ship. It is obvious that it will be the formation of the ribs of the ship which will determine the lines.

If the ribs of a ship were merely straight pieces of iron bent at certain angles, the shipbuilder could work from a small drawing, and just make the ribs so many times larger than those in the drawing. He might use that simple plan even if the ribs were bent in semicircles, but to get all the different complex curves of hundreds of ribs required to produce the shape from bow to stern, by merely multiplying the lines of a small drawing, is quite out of the question.

The matter would be simplified if the shipbuilder could draw his ship full-size upon a blackboard. This suggestion may seem rather absurd when one considers the size of an Atlantic liner or a battleship; but that is what the shipbuilder really does. He would require a great ladder to get up to a blackboard of such dimensions, so he lays it on the floor; indeed, he makes the blackened floor of an immense room serve as a blackboard, this room being known as "the mould-loft."

Having chalked off a *profile*, or side-view, of the ship's hull (see Fig. 16), he draws also a *body-plan*, or what one might describe as the ship's waist-measurement, at different points. Then he draws a bird's-eye view, or plan, of the ship, or a *half-breadth plan* is sufficient, as the ship is equal-sided. With these three chalk drawings the builder arrives at the curves of the full-sized ribs. He bends a piece of flexible wood into the form required, and then chalks the shape of the rib upon the floor.

But how are the workmen to get those chalk drawings away with them to the works? They must bring the floor of their own workshop up to the mould-loft, and have shapes of the ribs transferred to it. Of course the workmen have to take their floor to pieces to carry it, but the planks are placed in their proper positions in the mould-loft, and the shapes of the ribs are drawn on with

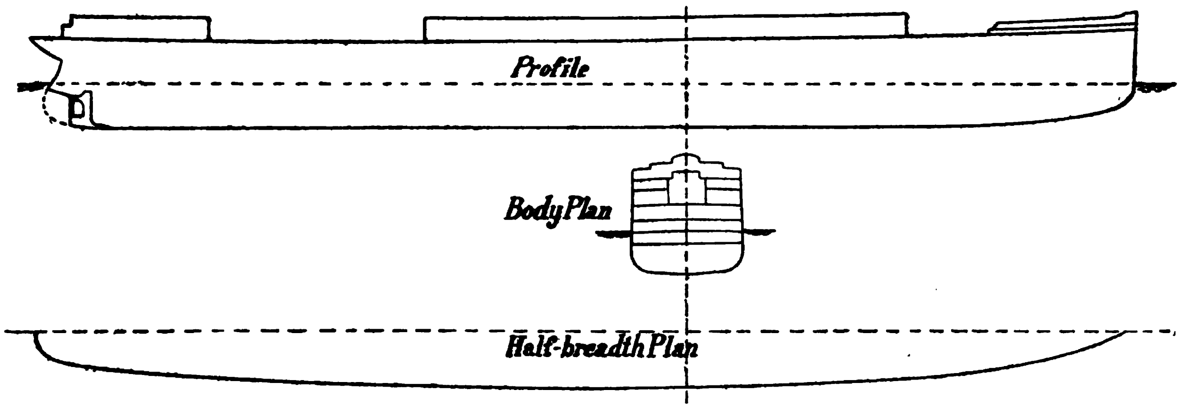

FIG. 16.—THE DIFFERENT KINDS OF PLANS REQUIRED OF A SHIP.

a sharp knife, as chalk marks would be too easily erased. The largest rib is cut, or "scrieved," first of all, then the next in size is placed within that, and so on. The planks of this *scrieved* floor are carried back to the workmen's quarters, where the floor is relaid.

Before the workmen can bend the steel bars, or "angles," into shape, bars must be raised to a white heat. It is obvious that these white-hot angle bars cannot be brought on to this wooden floor, upon which the forms of the ribs have been scrieved; but a very convenient plan is adopted.

When considering the manufacture of iron, we saw that if all the carbon were burnt out of the iron, the remaining pure iron was so soft as to be useless for most purposes. This soft or very malleable iron comes in very conveniently for making patterns, or *templates*, of these curved ribs. The cold metal bars are bent with ease, to conform with the curved lines representing the ribs.

When a soft iron bar has been bent into the form of a rib, it is taken over to a heavy cast-iron floor, which is riddled with holes, or sockets, in which metal pegs may be placed. A row of these pegs is arranged around the curved line of this soft iron template, so as to fix it firmly in position, and the red-hot angle bar, which is to form the real rib, is brought out of a long furnace, and bent against the template. It is then clamped down in position by a second row of pegs arranged along its other edge, and it is held in this position until it has cooled.

In another part of the busy works steel plates are being prepared, to form the shell of the ship. In most cases these are less than one inch in thickness, but it is no light task to make about five hundred holes around each plate for the purpose of riveting the plates together. There will be somewhere about ten million holes to be made in the plates of an Atlantic liner. It would take a man a long time to drill one hole by hand in a solid plate of steel, and even to drill such a number of holes by machinery would occupy too much time. The shipbuilder saves time by having very powerful machines, which punch a hole right through the plate with a single downward stroke. Of course it requires considerable energy to push a blunt metal tool straight through a heavy sheet of solid metal, but these punching-machines are quite equal to the task. There are large machines for rolling the plates, while other machines "shear" and "joggle" the edges so that the plates will be of correct size and overlap properly.

The prepared ironwork all makes its way to the yard in which the ship is to be erected. The first thing is to lay the keel. When some of us were boys our one idea of a keel was a heavy piece of lead or iron shaped so as to project downwards from the ship; but the keel of a modern liner might be described as a long gutter made of heavy steel plates. Towards the middle part of the ship this long gutter arrangement is only slightly bent. In other words, it is like a broad shallow gutter, while towards the bow and the stern it takes the form of a deep and narrow gutter. Along the centre of this "flat keel-plate" is set up the vertical *keel-plate*, which is just like a heavy girder. These two parts are well riveted together, while the base of each rib is also riveted to these two parts which form the keel.

After the skeleton of the ship is set up with its full complement of ribs, crossbeams, and bulkheads (or transverse walls), all in position, the ship is plated. Most of the riveting is still done by hand, although there are mechanical riveters, powerful hydraulic riveters being used for very heavy work.

In the old days of wooden ships the seams of the planks forming the shell had to be caulked with tow or yarn, to make them water-tight, and in the modern steel ship we find compressed-air machines busy caulking the seams of the steel plates by hammering the edges of the plates.

In order to prepare all the woodwork and other fittings for the interior of the ship, a large number of carpenters, joiners, blacksmiths, plumbers, electricians, riggers, mechanics, coppersmiths, painters, and so on, are employed. In the joiners' department we find complete cabins fitted up, so that the shipowner may see exactly what the builder proposes to make for the ship.

To return to the outdoor work, we can see that it has been a comparatively easy thing to lift the different parts of the ship and place them in position. But when these have been joined into one huge piece to form the ship, the total weight may be anything up to sixteen thousand tons, which is not a weight to be moved easily. Great care must be taken to see that the builder will have no difficulty in launching his ship when ready. The builder is not going to supply the energy to take his ship into the river. He depends upon the fact that one mass of

By permission of *The Fairfield Shipbuilding and Engineering Co., Ltd, near Glasgow.*

LAUNCHING A BATTLESHIP

This photograph shows H.M.S. Indomitable entering the water for the first time. The fixed ways and the moving ways are seen clearly, while the heavy chains or "earth anchors" are seen dragging along the ground.

matter attracts another mass, and that the earth, being so very much greater than any object upon it, possesses an overwhelmingly predominant position in the question of attraction.

The builder takes care to build his ship on a declivity sloping down towards the river. He must not make the decline too great, or the ship could not be properly launched. Careful calculations are necessary to arrive at the exact declivity required for any particular ship.

The keel is laid upon piles of wooden blocks, the height of each successive pile increasing towards the bow. If one walks underneath the middle part of a great liner, one is impressed with the flatness of the bottom. Indeed, it is as if one were under a great flat roof. I mention this in case anyone should imagine that the stilts, or supports, placed against the sides of the ship, are maintaining a very delicate balance.

When the ship is ready for launching, the keel-blocks are removed, and the vessel is allowed to rest on a pair of wooden rails, or "ways," which run parallel to one another, and form a wide track. Needless to say, the builder is not going to let his fine ship scrape along on these fixed ways. He gives the ship a wooden toboggan, as it were, upon which she can ride safely down the fixed ways. These "moving ways" are heavy beams of wood which rest upon the fixed ways. It is upon the moving ways that the ship rests when being launched. There is no need to strap the vessel to this simple toboggan, for her great weight pressing upon the wooden beams is just as good.

If the moving ways were laid merely upon the top of the fixed ways, the ship's weight would cause so much friction between the surfaces of the two wooden beams that the vessel would remain securely in the one position. But if a liberal supply of heavy grease is placed between the two surfaces, the friction is reduced so greatly that the moving ways slide down the fixed ways, and carry the heavy ship on their back. Of course those greased ways are raised into position, pressing upon the bottom of the vessel, before the piles of keel-blocks are knocked away. The ship, while resting upon the prepared ways, must be held back from gliding down the hill before the time comes. When the launching ceremony has been performed, two large trigger arrangements, one on each way, are released, and the great ship is pulled down the hill by gravity, dragging heavy anchor-chains with her, and safely launched into the river or into the sea. In order to make the launching ceremony as complete as possible, the pressing of an electric push may be arranged to switch on an electric current which releases the trigger arrangements.

In the illustration facing page 310 we see the launching of H.M.S. *Indomitable* from the yard of the Fairfield Shipbuilding and Engineering Company, Ltd., at Govan, just below Glasgow, on the River Clyde.

CHAPTER XXV

CONCLUSION

When considering the great achievements of modern machinery, we should remember that the ancients could produce excellent specimens of manufactures, but at what an enormous cost of labour! And when admiring the great tools which we use in some modern industries, we should keep in mind the fact that the ancients could carry out immense undertakings without these aids. Witness the great Pyramids and Sphinx of Egypt. But the building of these must have taken an enormous amount of human effort. Indeed, it is stated that one pyramid took the continuous efforts of one hundred thousand men for about fifty years.

In this connection it is interesting to note the following statement which I have extracted from an old book, entitled *Mathematicall Magick*, written about two hundred and sixty years ago. After referring to the Pyramids, the writer says: "Above all ancient designs, that would have been most wonderfull, which a Grecian Architect did propound unto Alexander, to cut the Mountain Athos into the forme of a statue, which in his right hand should hold a Town capable of ten thousand men, and in his left a Vessell to receive all the water that flowed from the severall springs in the Mountain. But whether Alexander in his ambition did feare that such an Idoll should have more honour than he himself, or whether in his good husbandry hee thought that such a microcosme (if I may so style it) would have cost him almost as much as the conquering of this great world, or whatever else was the reason, he refused to attempt it."

We have direct evidence that the ancients were able to handle huge pieces of stone weighing, in one case at least, as much as three hundred and eighty tons. Our largest crane to-day cannot lift half of that great weight. But what an enormous amount of human energy the ancients must have expended!

In the preceding chapters we have seen to what a great extent automatic machinery has relieved man of much manual labour, and enabled him to produce necessary articles and even luxuries at a cost which brings them within the reach of almost everyone. There is a true romance in the fact that much of the monotonous toil of man has been taken off his shoulders by inanimate machines of his own invention.

It is obvious that the introduction of machinery into many branches of industry has meant hardships for some particular generation of toilers, and we must consider these as martyrs in a good cause—the general advancement of mankind.

One fact which is very prominent in the preceding pages is that the real inventor very often suffered martyrdom on account of his zeal. To take only one or two instances: James Watt suffered much in his endeavours to produce a practical steam-engine. It was with a sore heart and a worried mind that Watt wrote: "Of all things in the world there is nothing so foolish as inventing." Fortunately he reaped financial success before his death, which occurred in the same year as that in which the late Queen Victoria was born (1819).

We have seen that Hargreaves and Crompton both died penniless and broken-hearted, though by that time many manufacturers were making money by means of these inventors' machines.

We have also seen how Lee, the Cambridge clergyman who invented knitting by machinery, met with no encouragement, and died of a broken heart in Paris. To-day many thousands of people receive handsome dividends earned by factories employing such machinery.

Then we recollect the hardships of poor Elias Howe, the American mechanic who invented the sewing-machine, and again how poor Palissy, the potter, broke up his household effects in order to feed his furnace during his last desperate experiment. These are but a few of the martyrs who have sacrificed themselves in laying the foundations of our modern manufactures.

When people are discussing the position of Great Britain as a manufacturing nation, one often hears the question of technical education brought forward as a reason why Continental countries, more especially Germany, can excel Great Britain in certain industries. One is apt to think of this as a problem of recent date, but that is not the case. In the old book (1648) to which I have referred in the opening paragraphs of this chapter, there appears the following sentence: "Ramus hath observed, that the reason why Germany hath been so eminent for Mechanicall inventions, is because there have been publike Lectures of this kind instituted amongst them, and those not only in the learned languages, but also in the vulgar tongue, for the capacity of every unlettered ingenious artificer." These words were written more than two hundred and sixty years ago. Great Britain has wakened up to the fact that technical colleges are an absolute necessity, and many of our modern colleges are excellent examples of what is required.

Another conclusion at which one may arrive after considering the methods of manufacture in different industries is that there is a great similarity between the actions of the machines used for different purposes. We can still divide all motions into the four divisions set forth by Aristotle, the tutor of Alexander the Great, more than two thousand year ago. These were described as *pulsio*, *tractio*, *vectio*, *vertigo*, which signify *thrusting*, *drawing*, *carrying*, *turning*.

A friend has remarked to me that we have become so accustomed to having things done for us by machinery that one might almost be surprised to hear that any action could not be performed by a machine. He suggested that we might even make machines to wash our faces. I have distant recollections, however, of an automatic bootblack which was set up at one of our large railway-stations. I was foolhardy enough to let the machine brush my boots on one occasion, but on making inquiries some time later I was informed that the automaton had been dismissed, and the human bootblack confided to me "that it had nearly taken the feet off a gentleman." Even if it were possible to get machines to perform all manufacturing operations, there would still be plenty for man to do. To manufacture articles of necessity and luxury, to distribute these and carry them all over the world, is not the only possible interest in life.

Indeed, there are many of us who are convinced that if every young man would take up a definite hobby, apart from his daily work, our country would be the better for it. There is too much idling away of time by the modern youth, and Cowper's words are still true:

> "An idler is a watch that wants both hands;
> As useless if it goes as if it stands."

And again we have the words of Ben Jonson:

> "Virtue, though chained to earth, will still live free,
> And hell itself must yield to industry."

APPENDIX

THE ORDER OF INVENTION

Fourteenth Century.

Spinning-wheels introduced into Great Britain.

Mechanical clocks (very imperfect).

Fifteenth Century.

Printing with movable type.

Sixteenth Century.

Knitting by machinery.

Seventeenth Century.

Newspapers printed (England 1622, U.S.A. 1690).

(*Not printed by machinery till* 1814.)

Eighteenth Century.

Spinning by machinery	1764
Watt's steam-engine	1769
Power-loom	1787
Experimental steamship	1788
Coal-gas for lighting	1792

Nineteenth Century.

Steam locomotive (Trevithick)	1803
Stephenson's locomotive "Rocket"... ...	1829
Matches with vitriol	1826
Lucifer matches	1829
Iron ships	1836
Sewing-machines	1845
Electric light	1858
Incandescent gas-mantle	1886